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JOURNAL
OF THE INSTITUTION OF ELECTRICAL ENGINEERS

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These two Forewords written by the President, Mr. T. E. Goldup, C.B.E., record, first, the general impressions gained at the Commonwealth Engineering Conference and the Eusec Conference he attended recently with the Secretary, and, secondly, his appreciation of the present health of The Institution oversea.

ROUND THE WORLD IN 75 DAYS

DURING the period 28th February to 12th May, I, in company with our Secretary, Mr. W. K. Brasher, and Mrs. Brasher, circumnavigated the globe in performing the very pleasing, if somewhat exacting, duties of attending, as the official representatives of The Institution, the fourth Conference of Engineering Institutions of the British Commonwealth, held in Australia, and the sixth Conference of the Engineering Societies of Western Europe and the United States of America (Eusec), held in New York.

The Conference of Engineering Institutions of the British Commonwealth is the result of an initiative displayed by the Councils of the three British engineering societies—The Institution of Civil Engineers, The Institution of Mechanical Engineers and The Institution of Electrical Engineers. In 1946 they adopted a suggestion put forward by The Institution of Civil Engineers that the friendly relations and fine co-operation between the Home and Commonwealth institutions, which have always flourished and had been so greatly strengthened during the recent war, should be consolidated and given coherent form by establishing a body in which the engineering institutions of the Commonwealth should be represented—normally by their respective presidents and secretaries.

Briefly stated, the aims of the Conference are to assist in the advancement of engineering in all its branches and aspects, to further the common aims of the constituent institutions, to secure mutual co-operation between those institutions in technical and professional matters, and to provide a platform from which pronouncements of professional opinion can be made.

The Conference first met in London in 1946, in Johannesburg in 1950, again in London in 1954, and this year in Australia, sessions being held in Sydney, Melbourne and Canberra. There are now 13 participating institutions, and the Conference has also established good relations with other bodies having similar interests, and particularly with Eusec.

Eusec, also owing its origin to an initiative from the three Home engineering institutions, was formed in 1948 and has aims practically identical with those of the Commonwealth Engineering Conference but, of course, with a more international ambit. At this year's Eusec Conference in New York, 19 institutions were represented—for the most part by their presidents and secretaries.

Although an account of the proceedings of these two important conferences will make interesting reading when published in due course, all I am able to give in this short foreword is a brief note of my general impressions.

In the first place, the proceedings themselves, and the many personal contacts I was able to make during the conference periods, amply showed not only the value and the necessity of these contacts but the very real need for collaboration and co-operation of this kind.

Every constituent institution of the conferences is deeply concerned with the problems of education and training for engineers and technicians. Their efforts in this direction must, of necessity, differ in kind and in extent according to local conditions—geographical, economic and social—but by the pooling of experiences and opinions on this important subject a common basis for training and common standards for qualifications are gradually emerging.

Again, and this applies, perhaps, more particularly to the Commonwealth institutions, opportunities for members to prepare and present original papers are in some areas understandably rather limited, and there exists, therefore, a real risk that individual engineers as well as the institutions themselves may experience a sense of isolation—of being cut off from technical contact with their confrères in other territories. It is, however, abundantly apparent that the conferences are creating the required channels through which the interchange of technical and scientific information can take place.

At no time have the accomplishments and the activities of the engineering profession been more sought after by governments than to-day, and it is probable that at

no other time have so many engineers, or so large a proportion of the whole body of professional engineers, been in the direct or indirect service of government departments. An important outcome of continuing conferences such as these is that governments can have professional men at their disposal whose qualifications are of a universally recognized high standard and who are in touch with the latest technical developments in spite of geographical obstacles.

Finally, and this is closely bound up with my previous point, it was brought home to me time and time again during my journey that engineers, both as individuals and collectively, are becoming increasingly aware of their potential value as a body of enlightened opinion and unified purpose, who could have an incalculable influence in directing technical achievements to serve the best interests of the human race.

T. E. G.

A ROUND OF FAMILY VISITS

THE journeys undertaken in connection with the Conference of Engineering Institutions of the British Commonwealth in Australia and the Eusec Conference in New York provided, in the opinion of the Council, an excellent opportunity for the President and the Secretary to visit as many as possible of the oversea centres of The Institution's activities—a pilgrimage which had never before been made to the same extent.

The planning of the electrical party's journey was carried out in conjunction with that for the corresponding parties from The Institution of Civil Engineers and The Institution of Mechanical Engineers, so that the combined pattern gave as complete a coverage of the oversea units of the three Institutions as possible.

Our round of visits had two main objectives—first, to meet as many of our oversea members as possible, and second, by personal contact and by discussion both formal and informal, to assess the adequacy and efficiency of the existing machinery for linking oversea members with the parent body.

In the latter connection, it should be remembered that there are no fewer than 7267 oversea members—about one-sixth of the total membership. Their interests, and those of The Institution, are served in different ways according to local conditions. Thus, where numbers justify it, an Oversea Branch may be formed. An Oversea Committee may serve a smaller community or more scattered area; and an Oversea Representative of the Council may act alone or in conjunction with a Branch or Committee. Provision is also made for the establishment of Joint Oversea Groups of members of the three British Institutions—of Civil, of Mechanical and of Electrical Engineers—in districts where no other suitable facilities exist.

In reviewing very briefly my personal impressions of the tour, I must at the outset record our sincere thanks to the Oversea Branches, Committees and Representatives, and to the Joint Groups, not only for the warmth of their welcome and the lavish hospitality they showered upon us, but for the endless trouble to which they went in arranging functions, both official and informal, at which we were able to make many invaluable contacts, and also for the thorough and impartial way in which we were everywhere briefed on local affairs.

Considerations of space preclude even a bare list of all the organizations we visited, not to mention the number of functions we attended in each territory. I hope, however, that it will not be considered invidious if I mention one or two examples which are typical of the enthusiasm and kindness with which we were received throughout the tour, and of the excellent arrangements made on our behalf.

At Baghdad, for instance, our two-day programme, arranged by the Iraq and Persian Gulf Joint Oversea Group, included luncheon with the British Ambassador and a meeting of the Joint Oversea Group where I, and also the Secretary, addressed over 300 engineers, many of whom had flown in from distant parts of the oilfields especially to attend. In addition, we were each day the guests of leading local engineers who arranged visits to meet influential people in official and engineering circles, as well as sight-seeing excursions.

In Bombay, the traditional garlanding in honour of the President and the Secretary and his wife, depicted very freely in the Indian technical and local Press, was the occasion of a most pleasant social function held at the Cricket Club of India, where Test matches have aroused the enthusiasm of Indians and English alike.

Our joint hosts in the Antipodes—The Institution of Engineers, Australia, and the New Zealand Institution of Engineers, who were also responsible for the general organization of the Commonwealth Engineering Conference—spared no effort to make our stay with them both profitable and instructive.

The visit to the Snowy Mountains scheme, the pleasant afternoon tour of the Blue Mountains, the inspection of the open-cast brown-coal project, are now just happy memories; but they are a reminder of the skill, initiative and drive one comes to associate with engineers 'down under'.

In New Zealand, the arrangements were made by the Oversea Committee. Within the space of only 12 full days we were received by the Prime Minister of New Zealand and by the Governor-General; were the guests of the New Zealand Institution of Engineers at official luncheons in Canterbury, Wellington, Hamilton, and Auckland; attended a Council meeting of the New Zealand Institution of Engineers; and took part in a

(*continued on p. 431*)

An Electrical Engineering Review

621.394.924 THE TELEPRINTER AND ITS APPLICATIONS

This article describes in some detail the electrical and mechanical ingenuities of modern teleprinters, now an accepted element of industry and commerce. Mr. Harrison was formerly Chief Engineer of the Automatic Telephone and Electric Co. and is now Engineering Consultant to them.

H. H. HARRISON, M.ENG., MEMBER

THE teleprinter is similar in many respects to the ordinary typewriter but can be operated from a distance over a land line, submarine cable, or radio link. It has, for several reasons, almost entirely replaced the older systems of telegraphy in the last two or three decades. An obvious merit it has is that the presentation of a message in block letters is greatly superior to that of manuscript, however good the writing may be. A second, and by no means negligible, advantage of the teleprinter is that the operator requires a much shorter apprenticeship than that necessitated by the older systems of telegraphy.

All makes of teleprinter have certain common features. The binary code is used, and a typewriter keyboard controls a mechanism which forms the combinations of currents representing the letters, figures, and the special-function signals required by a typewriter—such as letter and line feed and carriage return. The transmitter generates the current combinations of signal in the form of positive and negative or on and off pulses. In addition, an essential part of the teleprinter is a speed-governed electric motor which ensures that transmitting and receiving apparatus run at constant speeds.

Five terms of the binary code yield 31 signal combinations. For instance:

$$31 = 16 + 8 + 4 + 2 + 1 = 2^4 + 2^3 + 2^2 + 2^1 + 2^0$$

which would be written as 11111, and any one of the 30 other signals would be a combination of 1's and 0's. Fig. 1 shows the international code No. 2. These signals could be transmitted simultaneously (in parallel) over a single line at five different frequencies. The most usual method, however, is to transmit them successively (in series) by using rotary switches as distributors, with one installed at the transmitting end to collect the signal elements set up on the keyboard and send them over the line, and the other at the receiving end to distribute them to the selector mechanism which causes the printing of the transmitted character.

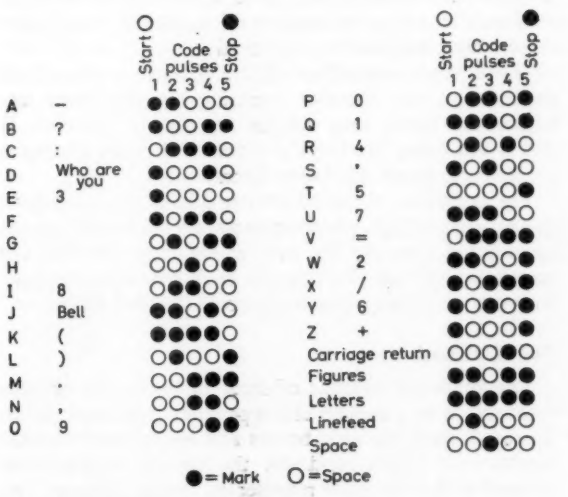
Synchronism

The rotary switches must not only run at constant speed but be approximately in phase, or confusion will result. Practical synchronism is secured by coupling the transmitting and receiving shafts of their motors through friction clutches, prefixing the five-unit code of each character by a start impulse and terminating it by a stop pulse. The receiving shaft runs about 8% faster than the transmitting shaft. Since both shafts are at rest at the end of each revolution, no phase difference can accumulate. The start signal and the five code signals are each usually 20 millisec in duration, while the stop signal is usually of 30 millisec.

Operating Conditions

The teleprinters produced by different makers require operating currents ranging from 20 to 50 mA, at ±48 volts. The voltage is provided by secondary cells charged from the mains, or where no batteries are available, the public supply is utilized. If the supply is direct current, the mains voltage is stepped down by either a potential divider consisting of a bank of lamps, or a rotary convertor. With alternating current, a step-down transformer and bridge-rectifier unit are generally employed.

The teleprinter motors are of the order of 0·1 h.p. They are usually shunt-wound d.c. machines and run at about 2500 r.p.m. Reduction gears are interposed where required. The governor is of the centrifugal type and short-circuits a resistance either in the field or in the armature of the motor. The speed is thus varied within certain limits with a constant mean.

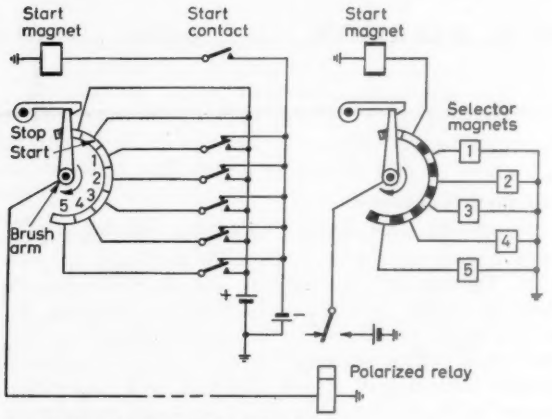


1 *The international code No. 2*

Basic Principles

The principles on which the teleprinter is based are illustrated in Fig. 2, which shows some details of the first practical teleprinter in use in this country.

The keyboard is similar to that of an ordinary typewriter. As each key operates, it arranges the five contacts representing the letter signal and also closes a start contact by which a start magnet is operated. The start magnet raises the latch holding the brush arm against the power of the yielding drive, and the brush arm starts to rotate. When the brush reaches the start contact, a start pulse is sent out over the line and operates a



2 *Basic principles of the teleprinter*

polarized relay, whereby a current is sent through the receiving start magnet. This, lifting its latch, frees the receiving brush arm, which sweeps over the shortened segments connected to the five selector magnets. As soon as both brush arms have started revolving, and while the letter signal is being transmitted and received, the start magnets are de-energized, and their latches drop in readiness to arrest the motion of the brush arms when these have completed one revolution.

The correct operation of the system as described depends on the operator releasing the depressed key before the brush arm reaches its resting position. If this is not done, the letter is repeated. Special measures are taken to avoid this faulty operation.

The operation of the teleprinter is thus the conversion of space signals (the written message) into time signals transmitted over the line and, at the receiving end, the translation of the time signals back into space signals recorded on either a paper tape or a sheet of paper.

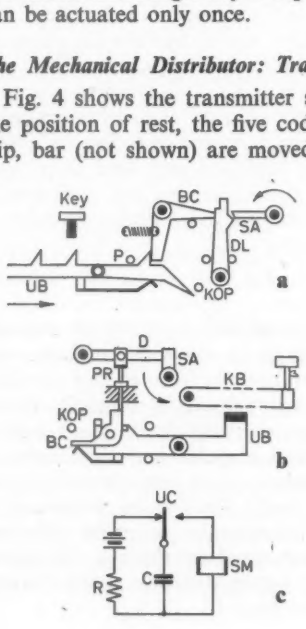
The Keyboard

The keyboard consists of three or four rows of keys arranged as in a commercial typewriter, and these, when operated, start the distributors and also set the selector mechanisms which send out the current combination allotted to the character represented by the operated key. In an elementary form of selector, five code bars are capable of sliding in a series of grooves in the base of the apparatus. They are normally held in position by the spiral springs attached to their left-hand ends. When a key is operated, its under-edge engages, say, three triangular projections on code bars 1, 3, and 5, and these are cammed to the right. At their right-hand ends they carry cams of insulating material, and as these move to the right they change the corresponding transmitter levers from their negative to their positive contacts, thus setting up the signal $+ - + - +$.

It has been mentioned that, if a key is held down after the transmitting cycle is completed, the signal set up is repeated, or, if the key is released at, say, half the succeeding cycle, a mutilated signal is sent out. There are a number of ways of overcoming this difficulty, and Fig. 3 shows three methods. In Fig. 3*a* the universal bar UB, operated when any key is depressed, carries a pawl P which has an abutment on its upper edge holding a bellcrank BC in the stop position shown. As UB moves to the right it rotates the bellcrank counter-clockwise, so that a detent lever DL is freed and with it the stop arm SA. Towards the end of the universal bar's movement, the pawl encounters a knock-off pin KOP, so that it is freed from the tail-piece of the bellcrank, and the latter snaps into its normal position. The detent lever is thus moved so that it is ready to catch the stop arm at the end of one revolution. A second revolution cannot take place until the operated key has been released. Fig. 3*b* shows a variant of this method; its operation is obvious. Fig. 3*c* shows an electrical method. The universal contact UC is closed when everything is at rest. The capacitor C is charged to the voltage of the battery and, when the universal contact is reversed, discharges through the start magnet. No matter how long a key is depressed, the start magnet can be actuated only once.

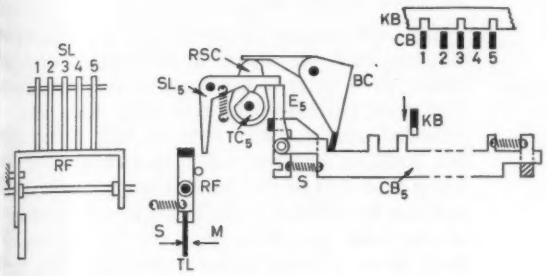
The Mechanical Distributor: Transmitting

Fig. 4 shows the transmitter selector mechanism. In the position of rest, the five code bars and a sixth, or trip, bar (not shown) are moved to the left by a bell-



3 *Methods of ensuring non-repetition of signals*

crank BC which comes into operation towards the end of a revolution. Pivoted to the left-hand ends of the code bars are five levers E_{1-5} which support the horizontal arms of selector bellcranks SL_{1-5}. When a key is



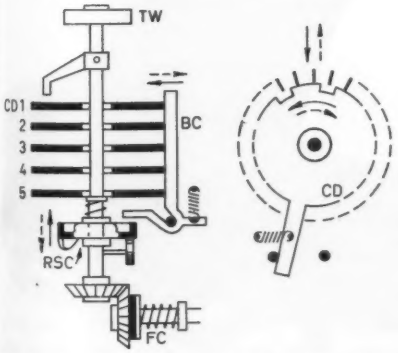
4 *Transmitter selector mechanism*

operated, the camshaft starts to revolve, freeing the bellcrank as the reset cam RSC moves clockwise. The lower arm of the bellcrank now frees the code bars CB, which moves to the right if gating slots in the key bars KB permit. The corresponding selector bars rotate clockwise, and their tail-pieces operate the rocking frame RF so that it reverses its position. In this way the start pulse and the marking pulses of the letter signal are sent out to line, followed by the stop pulse. The rotating brush arm sweeping over a group of circularly disposed contact blocks has almost entirely given way to cam-controlled contacts operated in the manner described.

The Mechanical Distributor: Receiving

The receiver selector mechanism may be in the form of code bars or discs. If the teleprinter employs a type wheel, aggregate-motion linkage can be used to position the type wheel so that the desired letter appears at the printing point.

Fig. 5 shows part of a well known British teleprinter in which code discs and a type wheel are adopted. The code discs CD are rotated slightly so that an aligned

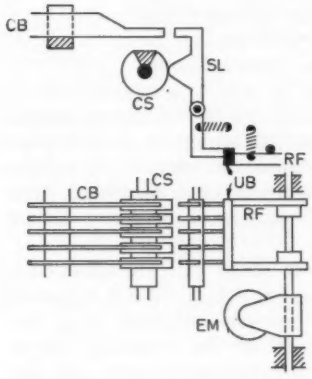


5 *Receiver-selector mechanism using code discs and a type wheel*

slot is presented to one and only one of the bellcranks surrounding the discs. When a bellcrank enters an aligned slot, it enters also the path of a stop arm mounted on the yieldingly driven shaft and arrests its motion, with the desired letter on the type wheel TW at the printing point. After printing, a reset cam RSC lifts the operated bellcrank clear of the code discs and of the stop arm, and the type wheel resumes rotation.

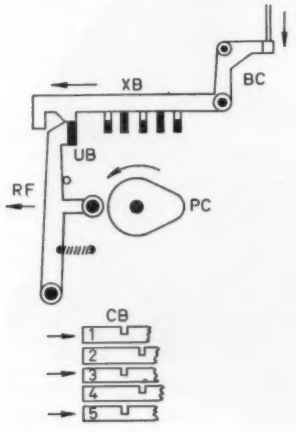
A selector for operating code bars is shown in Fig. 6. An electromagnet operates a rocking frame which carries a universal bar UB facing the tail-pieces of five selector levers SL. Each lever is controlled by a cam which frees it, provided that it is not interfered with by the universal bar. When non-interference occurs, the selector lever, under the action of its spring, rotates so that its upper end pushes the corresponding code bar CB to the left.

Fig. 7 shows an arrangement for actuating the type bars of a teleprinter. The crossbars are each provided



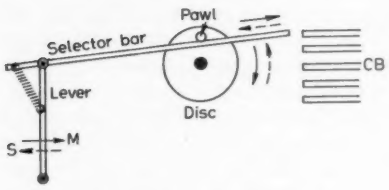
6 *Code-bar selector*

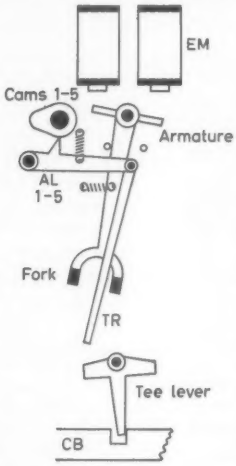
with a bellcrank connected by a wire link to the type bar. When the code signals have been set up, the printing cam acts on a rocking frame carrying a universal bar. As this bar moves to the left, the selected crossbar drops into the aligned slot, and further motion of the universal bar draws the crossbar to the left so that the bellcrank is sharply rocked clockwise and imparts a staccato pull



7 *Arrangement for actuating the type bars of a teleprinter*

to the type bar. As the universal bar is returned to normal it cams the crossbar out of the slot, and the code bars can be returned to normal in readiness for the next letter signal.





8 (above) *Positioning of code bars*

9 (right) *Alternative method of positioning code bars*

There are a variety of electro-mechanical devices for positioning a group of five code bars in accordance with any of the 31 combinations of the five-unit code. Fig. 8 shows one form, in which a selector bar is pivoted to a lever actuated by the receiving electromagnet (not shown) and carried through an arc embracing the five code bars. In addition, the selector bar receives a forward (selecting) movement or a backward (non-selecting) movement and actuates or does not actuate the code bars successively.

In Fig. 9, five actuating levers AL are operated in succession by a series of cams. A trip rod TR is pivoted to each lever, and the rods are embraced by a fork whose armature is operated by the receiving electromagnet EM. When the armature is attracted, the fork carries all the trip rods over to the right, the selected levers are operated by their cams, and their trip rods act on the tee levers which operate the code bars.

The modern page teleprinter shown in Fig. 10 is capable of operation at 100 words/min. It requires only 15 × 13 in. table space and is 11 in. high. Weighing 42 lb, it is eminently suitable where minimum weight and size are essential.

Keyboard Perforator

The keyboard perforator (Fig. 11) furnishes a punched tape for use in a transmitter, or tape reader as it is now more generally designated. The usual perforated tape is $\frac{11}{16}$ in. wide and is provided with a centre row of feed holes and five rows of punched holes in two groups: 1, 2 and 3, 4, 5. The feed holes are ten to the inch and may be punched in the blank tape beforehand or provided simultaneously by the perforator itself when a letter signal is punched. The fact that the first two holes are above, and the succeeding three below, the feed holes ensures that the tape is not inserted upside down, while punching the feed holes slightly in advance of the signal holes prevents the tape being changed end for end.

Receiving Perforator

The keyboard perforator can be adapted to be operated over a line circuit. With start-stop control the keyboard is replaced by a battery of cams. The punching and feed arrangements are identical.

The line signals can be reperforated on tape, which can then be used in a tape reader for transmission over a further line circuit, the whole arrangement constituting a tape relay, the outgoing signals of which are regenerated.

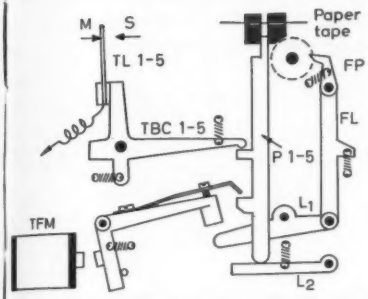
Tape-Controlled Transmitter (Tape Reader)

Fig. 12 shows a tape transmitter in which peckers P_{1-5} are presented to the paper tape. They control five transmitting levers TL_{1-5} by reason of the lugs on the

10 (left) *Modern page teleprinter*

11 (above) *Keyboard perforator*

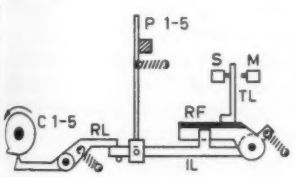
left-hand side of each pecker. If a pecker is confronted with an imperforate portion of tape, it cannot rise, and the transmitter lever is not reversed. If, however, a pecker is confronted with a hole in the tape, it rises



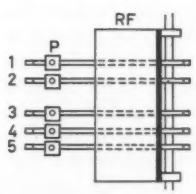
12 *Tape reader*

under the action of the spring-controlled lever L_2 and enters the tape. In doing so it places the transmitter contact on to the marking busbar. The tape-feeding magnet TFM is pulsed at a predetermined rate and when operated withdraws any selected peckers FP and operates the feed lever FL. All peckers are held clear of the tape until the feed operation is completed. When TFM is de-energized the peckers are again presented to the tape and act as already described.

A single transmitting lever is employed in the tape reader shown in Fig. 13. Bearing on the five intermediate levers are a series of levers RL which are sequentially operated by cams C_{1-5}. When a cam operates a lever it frees the left-hand end of the intermediate lever IL, and the pecker rises if not interfered



13 *Single-lever tape reader*



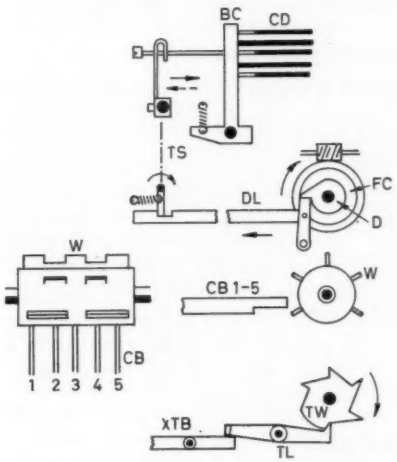
with by an imperforate portion of the tape. This action rotates the rocking frame RF, thus moving TL from its normal position S to the mark position M of the battery busbar.

The transmitter shown in Fig. 12 is generally used for time-division-multiplex methods of operation. For single-channel start-stop operation, the single-lever reader shown in Fig. 13 is the type most generally employed, as there is only one contact to be kept in order. (It is of interest, however, to note that one of the manufacturers of such transmitters has reverted to the rotary-switch type of distributor, as shown in Fig. 2.)

Automatic Through-Switching

In a large telegraph network it is becoming increasingly the custom to switch calling and called stations through to one another automatically. Telegraph interconnection is thus carried out in the same way as telephone communication.

The originating operator prefixes a series of routing



14 *Identification of teleprinter signals where subscriber systems are used*

signals, which are received, together with the intelligence signals, at the nearest main office on a receiving perforator to which a transmitter is attached. The tape constitutes a store, and the message is transmitted, when a free route has been found, automatically. The switching mechanism is partly electronic and partly of the type employed in the automatic switching of telephone traffic. In a large office, traffic from groups of lightly loaded circuits may be concentrated so that it may be handled by a few operators. This practice results in economies in teleprinters and in staff, and what is sometimes the most important of all, the saving of floor space in the main office.

Where teleprinters are switched through on a subscriber system, it is very important that the identity of the called station should be known. Otherwise, important commercial information might get into the wrong hands. The means for identification must not be in the called station's power.

Fig. 14 shows an arrangement by which this can be effected. The calling station operates a 'who are you' key, which at the called station causes one of the 31 bellcranks such as BC to operate. This causes trip spindle TS to move detent lever DL to the left, allowing

a spindle frictionally coupled to a wheel driven by a worm to start rotating. The spindle carries a barrel, on the periphery of which a number of plates or wards W are mounted. These wards act on the code bars CB_{1-5} successively and send out the code designation of the called station.

At the end of the revolution of the spindle, it is locked against further motion by the stop cam D. During the revolution a toothed wheel TW actuates lever TL, which operates the trip bar of the station's transmitter. The whole operation is entirely automatic and cannot be interfered with by the station being identified.

The Teleprinter and Multiplex Operation

The introduction of frequency-division multiplex has extended very considerably the use of teleprinters in the national telegraph network. The valve amplifier makes it possible to use powers of the same order as those used in telephony, while the audio band of frequencies can be divided into about 24 sub-bands, each providing a teleprinter channel. Thus the telephone-cable network can be used, and coaxial cable offers still greater possibilities. This system is much more flexible than the older time-division multiplex, which, at repeater stations and at points where a channel has to be diverted to a station not on the main line, requires complicated arrangements and skilled supervision.

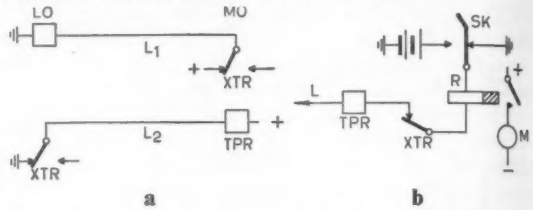
The Teleprinter and Radio

A radio link, being subject to fading and disturbance, makes successful teleprinter operation difficult. The omission or insertion of signal elements leads to the wrong letter being recorded. This is partly overcome by translating the land-line signals into a three-out-of-seven code, which yields 35 combinations. Counting apparatus is provided, whereby if two, four or five marking elements are received an alarm is operated and a signal sent back to the transmitting station, on which the transmitting tape is drawn back and then released to correct the faulty signal.

Circuit Arrangements

Fig. 15*a* shows an arrangement in which a local office LO is connected to a main office MO by two lines, the receiving 'leg' L_1 and the transmitting line L_2. No signalling battery is required at the local office, and the motor there is driven from the public mains. The local instrument may be normally unattended, and to save the motors running needlessly the arrangement shown in Fig. 15*b* is sometimes introduced, using a single line and a signalling battery at each end. When the start key SK at either end is reversed, slow-release relays R operate and close the motor circuit at both stations. The relay is slow to release so that the motor circuit is held closed during spacing, no-current intervals.

Fig. 16*a* shows two teleprinter stations permanently connected through line L. At rest, transmit-receive switch TRS places both receiving parts of the teleprinter in connection with the line. When one of the transmitters is operated, the t.r. switch is reversed and the transmitter is connected directly to line and the distant teleprinter. Branching from the output end of the line is a path to the receiving portion of the teleprinter via a leak resistor LR. In this way the outgoing signals are recorded on the home teleprinter.



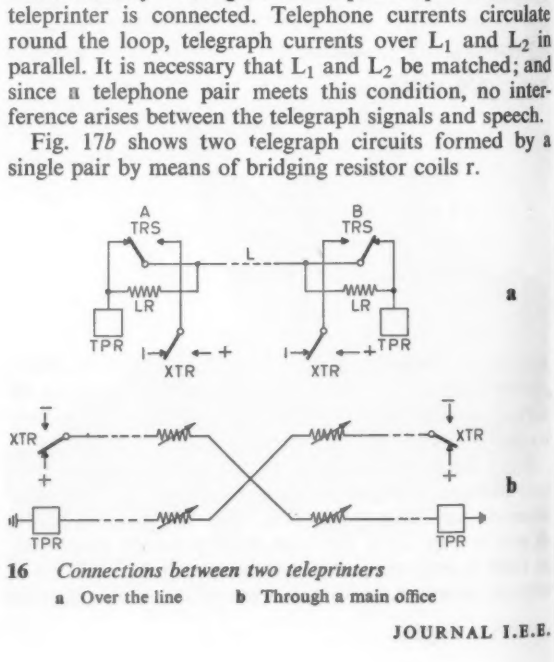
15 *Two-line connection between local and main offices*

Fig. 16*b* shows a circuit in which two teleprinters are permanently connected through a main office. Both-way operation is secured by the use of two lines, and variable resistors are provided to adjust the current to a suitable value for correct operation.

Nowadays the aerial line with earth return has largely been replaced by the telephone pair, and by superposition the pair may be arranged to furnish a telephone channel and a telegraph channel quite independent of one another.

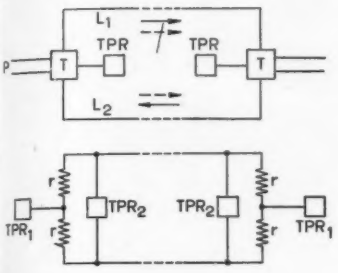
By means of an arrangement such as that shown in Fig. 17*a*, a teleprinter circuit can be coupled to a telephone pair, and speech and signalling can proceed simultaneously. The coupling is by means of transformers T, whose two windings couple the speech currents to the loop circuit formed by lines L_1 and L_2. The secondary winding has a mid-point tap to which the teleprinter is connected. Telephone currents circulate round the loop, telegraph currents over L_1 and L_2 in parallel. It is necessary that L_1 and L_2 be matched; and since a telephone pair meets this condition, no interference arises between the telegraph signals and speech.

Fig. 17*b* shows two telegraph circuits formed by a single pair by means of bridging resistor coils r.



16 *Connections between two teleprinters*
a Over the line **b** Through a main office

Yet another method of obtaining simultaneous telegraph and telephone service out of a single telephone pair is known as *sub-audio telegraphy*. This depends on the fact that a bandwidth of 200 c/s is adequate for telegraphy, while 300–3000 c/s is necessary for telephony. By the use of high- and low-pass filters, these two bands are separated.



17 *Coupling of teleprinter circuit to a telephone pair*

Another method of obtaining more than one channel from a single pair is the frequency-division-multiplex system in which the line-frequency band is used to furnish 18–24 channels. The channel frequencies are unequal multiples of 60 c/s, the first being $60 \times 7 = 420$ c/s, the second, $60 \times 9 = 540$ c/s, and so on. The channel and space bands are each $120 + 120 = 240$ c/s. The sending voltage depends on the number of channels in use simultaneously and is less than one volt. The receiving voltage is lower still.

The Future

The teleprinter, together with frequency- or time-division multiplex, is effecting a complete metamorphosis of not only the British but also the world's telegraph network. Cable and radio channels will link nation to nation. The necessary circuit set-up will be effected by means of automatic switching.

Taking the normal teleprinter as using 7·5 units or bauds per letter and reckoning the average word plus space as equivalent to six letters, the transmission speed is $50/45 = 1{\cdot}11$ letters/sec or 66·6 words/min.

A link such as that between America and Europe is costly, and the 'holding time' of a traffic unit should be kept as short as possible. Manufacturers are alive to this necessity, and teleprinters are now being made capable of higher speeds to meet this condition. High-speed re-perforators have also been produced. Still higher speeds may be attained by the adoption of electronically operated tape readers, while the recently introduced magnetic tape recorder, designed to replace the normal re-perforator, is promising.

Nowadays a managing director is in continuous touch with his provincial branch establishments by telegraph, and he rents not a line but a channel. In the near future it will be possible for him to obtain automatically a telegraph connection to his foreign agents or factories. All this is not due to the teleprinter alone. It is made possible by multiplying the channel capacity of an existing line plant by the methods outlined above.

Summary

The adoption of carrier-current transmission and automatic switching means that any telegraph office in a network can reach any other in the same network without the need for re-transmission at intermediate points. This results in staffing economies and saving in floor space and, consequently, in the size and cost of buildings. The use of a common line plant, the telephone cable, for both telegraphy and telephony is also a considerable economy, especially from the maintenance point of view, and the aerial line with earth and battery signalling is fast disappearing in most countries. It seems certain that ultimately the independent telegraph networks of the world will be merged into one international network.

A ROUND OF FAMILY VISITS (contd. from p. 424)

reception at which we met and addressed 290 members and their wives. I visited the Universities of Canterbury and Auckland, attended the Governor-General's garden party, gave several Press conferences, and recorded a discussion which was later broadcast from station 2YA. In addition, we inspected hydro-electric, geothermal and steam power stations and many other engineering works.

These were some of the main items in a very full programme which, however, was most pleasantly relieved by the numerous kind hosts and hostesses who welcomed us into their homes and arranged excursions for our recreation and delight.

It was the same story wherever we went—in Bombay, Delhi and Calcutta, in Singapore and Kuala Lumpur, in Sydney, Melbourne and Canberra, throughout Canada, and in the United States—always the same care and consideration in planning: always the same smooth-working organization. A feature which gave special pleasure was the number of functions which were graced by the presence of ladies; and another lasting memory is the number of speeches one was called upon to make—often at only a few minutes' notice.

As to the main objectives of the tour, the obvious enthusiasm with which we were everywhere greeted, and the opinions expressed on every hand, indicated that the oversea affairs and activities of The Institution are organized on sound lines and are being administered efficiently and that the machinery is working very well.

Another impression, which I formed as the result of my many discussions with members of governments and other officials, is that everywhere the engineer is being held in ever higher esteem in official and industrial circles—clear evidence of the need for engineers to equip themselves and to be ready and willing to play their part in shaping the destinies of mankind in more ways than by contributing the marvels of their skill.

The magnitude of the tour demanded an immense amount of initial detailed preparation and planning, and I conclude by thanking most sincerely all those, both here and abroad, who were responsible for the programme. The fact that the whole tour proceeded smoothly and to schedule is a tribute to those whose meticulous care characterized all the preparations. T. E. G.

(Left) The Soviet engineers inspect the Loch Garry hydro-electric scheme in the company of some of their British hosts. They are standing on the roof of the fish pass at the dam. (Right) The delegation watch the Poulary fish trap in action. The heck which is used to prevent fish ascending the river is in the background

As Others See Us

Some Impressions of Britain by Mr. F. G. Loginov, Deputy Minister of Power Stations in the Soviet Government

In recent years, a number of delegations of engineers from Britain have toured Russia and have brought back ample accounts to satisfy the curiosity of their less-travelled colleagues. The report of the six-man delegation appointed by the three engineering institutions to study hydro-electric development in the Soviet Union was published last May. It is not so often, however, that we have the opportunity of hearing the reciprocal point of view.

The following article describes the impressions of the delegation of Russian engineers who toured this country last September and October under the leadership of Mr. Loginov. They were entertained to luncheon at the Savoy Hotel by the President and Council of The Institution on the 11th October 1957.

The Russian engineers accompanying Mr. Loginov were Mr. A. Y. Kuznetsov, chief engineer of the administration of building of Stalingrad G.A.S.; Mr. S. N. Andrianov, head of Dneprostroya; Mr. N. D. Vesolov, deputy head of exploitation administration; Mr. M. D. Kozlov, chief specialist of the Leningrad Section of hydraulic engineering; Mr. G. A. Radchenko, director of the Leningrad branch of Hydroprojects; Mr. H. E. Anguladze, chief engineer of Tbilissk Section of hydraulic engineering; and Mr. A. B. Grishin, specialist of the U.S.S.R. 'Gostroya'.

At the end of September 1957, a Soviet delegation of eight power engineers visited Britain—a highly developed industrial country whose people have made invaluable contributions to the art, learning, culture and technology of the world.

Some of us had previously been abroad, but most were travelling for the first time. We were therefore anxious about the forthcoming meeting with our British colleagues in our own fields of work. During our extensive travels throughout the country, full of pleasant impressions and now of agreeable memories, we had the opportunity of convincing ourselves of the hospitality, friendliness and goodwill of the British people. We very much liked their healthy humour—a good, timely joke constantly adorned the life of the people.

To us, Soviet citizens, used to the wide spaces of our own country with its forests, fields and meadows, the love the British have for nature was particularly impressive, as well as the general protection and care which are afforded to it. With warmth in our hearts, we frequently saw parents and children lovingly tending the gardens of the houses in which they lived, in towns and villages everywhere.

Wherever we went, we saw demonstrations of the

love of work of the British people and their effort to fulfil their tasks with accuracy, skill, and economy of work and material resources. The results of the labours of British workmen, engineers and technologists are remarkable for their quality, economy and good planning.

Hydro-Electric Resources

Most of the delegates were specialists in hydro-electric construction, working either directly on building sites or in the research and development organizations.

We had known for a long time that the construction of hydro-electric stations in Britain—a country with a large volume of coal production—has not the same scope as in certain other countries of Western Europe, not to mention the United States. The share of water power in the present energy balance of Britain is not considerable and, so we were told, represents not more than 3% of generating capacity or 2% of total output. Such a position, we understand, is not the result of lack of attention to the utilization of water power resources, but is due rather to the absence of those resources. To our considerable interest and profit, we became familiar with a number of established hydro-electric stations and with some in construction.

As hydro-electric engineers, we were gratified to observe that in Scotland, where 90% of the functioning hydro-electric power stations are to be found, the proportion of employment of hydro-electric power resources has reached 32% of the total, and additional construction will enable this to be increased to 60% in the next five or six years.

We have always considered that hydro-electric stations, the value of which lies in the fact that they do not require fuel but use a source of energy ever renewed by nature, must be widely integrated into the total generating scheme and properly linked where possible with the thermal power stations. High productivity of personnel, the cheapness of water power and the rapidity with which hydro-electric groups can be brought into action, all contribute to making hydro-electric stations indispensable elements of modern power Grids, increasing their reliability and economy.

Acquisition of Land

Together with all this, we understood the difficulties which are in the way of hydro-electric development in Britain—problems which are non-existent in our own country. I have in mind questions of dispossession of land for hydro-electric installations and particularly for reservoirs. In conditions of private ownership of land, compulsory acquisition of large areas is inevitable and not only considerably complicates the construction of hydro-electric installations but also retards the projects and to some extent reduces the efficiency of utilization of the hydro-electric resources: it may, for instance, influence the degree of regulation of the discharge.

In Scotland, of course, which has a mountainous topography, questions of compulsory acquisition are reduced to a minimum, and this, together with the possibility of establishing high working heads, has facilitated the construction of a large number of hydro-electric stations.

From technical literature we know that, in order to employ existing hydro-electric power resources in various Western European countries, a relatively large amount (compared with the obtained power) of heavy work has frequently to be undertaken before the construction of stations can begin. But the present state of building technique and the concomitant methods of work production make it relatively easy to surmount obstacles which, ten years ago, placed such projects in the low-efficiency category, not justifying the investment of resources in their realization. In the Scottish power-utilization scheme we think these conditions played their part and made possible the construction of six hydro-electric stations in the Conon Valley of a total capacity of 107 MW, for which it was necessary to construct 30 km of tunnels. Similarly, the hydro-electric stations of the Breadalbane group, with a total capacity of 120 MW, involved the construction of 90 km of tunnels with diameters from 2·0 to 5·3 m.

Conservation

The inspection of several working hydro-electric stations, and familiarization with the schemes of energy utilization of streams in Scotland, particularly in the north, prompt us to comment on a characteristic feature —the remarkably careful regard which is paid to the conservation of water in order to obtain the maximum possible utilization.

This tendency is demonstrated in a variety of ways: the collection of additional water into the topmost reservoir, which, in addition to increasing the catchment area, makes it possible to use the discharge at a high head; extensive employment of controlled regulation of the water flow by the system of little reservoirs; and the utilization of any fall, even with light discharges, in spite

Mr. Loginov (fourth from right) and his colleagues enjoy the view at Loch Quoich while standing on the top of the 122 ft-high rock-filled dam

The dog is a Scotch Terrier

of the quite small amount of power thus obtained. The building of a great number of small hydro-electric stations, with inevitably some sacrifice in efficiency, is apparently justifiable in the conditions in Scotland, with limited water-power resources.

In the working out of schemes of water-power usage considerable attention is given to the conservation of natural resources, fish preservation and safeguarding the landscape. Evidently as a result of this latter consideration, many structures, even the small ones, are faced with natural stone and have an elegant appearance. The simplicity of the interior and exterior finish, for which hewn stone is used, is particularly distinctive.

The predominance of diversion schemes seems to be a particular aspect of hydro-electric stations. The existence of only two stations of the type adjacent to the dam—Pitlochry and Torr Achilty—indicates immediately the normal approach to that problem.

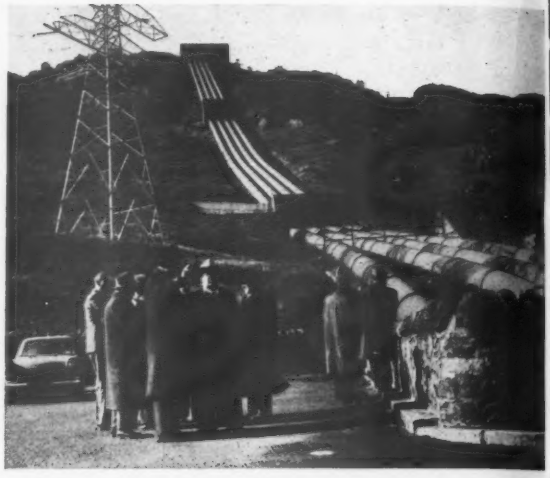
We were very interested in the steps taken to preserve the fish resources in the rivers and lakes of Scotland. Well-conducted research made it possible to find successful methods of construction of fish ladders like those we saw at the Torr Achilty dam. The efforts directed to the conservation of fish resources—fish ladders, breeding installations for small fish and various types of protective installation—gave positive results, and the building of hydro-electric stations may lead not to a reduction in the quantity of salmon and trout, but to an increase.

Praise and Criticism

We can truthfully express our satisfaction at the method of construction of hydro-electric installations which we had the opportunity of seeing. This opinion relates to the high quality of the work, the accuracy, good finish and planning, and the general avoidance of superfluity. It is true that the siting of the installations on rock makes it possible to construct them with smaller work volume, i.e. economically. At the same time, the well developed building industry in the country, the large number of industrial centres with relatively little distance between them, the fact that there is no difficulty in bringing labour to the site, and the good roads and connections, make it possible to minimize the indispensable volume of secondary construction at the site—repair workshops, warehouses, woodworking shops, special quarries, houses, cultural and living amenities, etc.

It follows that it is possible to reduce to a minimum the preparatory period of construction and to produce the work with a small number of building personnel, which does not increase substantially even over a period of years with the over-all increase in the volume of work.

On the other hand, it was difficult to support certain aspects of the work. For example, we were informed that in places it was the practice to pour concrete during only ten months of the year, whereas the climatic conditions would have made it possible to do so without particular difficulty all the year round. Also, on the construction sites there were machines of clearly obsolete design and an insufficiency of what is called in Soviet Russia 'small mechanization', which substantially increases manual labour.



The delegation visit the Loch Sloy scheme. Each of the pipes supplies a 32·5 MW generating set

These small criticisms are in no way meant to diminish the merited success which has been achieved by our British colleagues in our field of work—the research workers, planners, designers, engineers and builders—who have carried out a great volume of work at a high technical and practical level with small resources and in a very short time; it is impossible not to express to them our feelings of deep esteem.

Machinery Production

Britain has long been renowned for its production of machinery. What we have seen in the field of power engineering confirms this well earned reputation. The factories of the major companies produce excellent, quite up-to-date, powerful and varied equipment for power stations and electrical Grids.

One company which we visited has had great experience with all modern types of hydro-turbines, and we were very interested to have the opinions of this company on a variety of questions: for instance, that there is no need to provide quick-closing gates upsteam of the station on run-of-river plants; that there is no need to reduce the runaway speed of hydro-turbines by means of braking systems, since it is preferable to increase the safety margin in the design of the hydro-generators; and that it is possible to increase the limit of employment of variable-pitch runner-blade hydro-turbines to heads of 80–90 m.

From what we understood, this firm was then building a hydro-electric plant of about 200 MW with radial/axial turbines using runners 6 m in diameter. In the

building of these runners, much use was being made of arc welding. A similar problem confronts our own machinery constructors, who must produce even more powerful plants for the hydro-electric stations Bratski and Krasnoyarsk, now being built in Siberia.

Conclusion

In dealing with my impressions of our travels in Britain, I have paid great attention to hydro-electric stations; this is easy to understand since I myself am a hydro-electric engineer.

However, it is necessary to acknowledge the creative work of the British scientists, engineers and workmen who made it possible to build the nuclear power station at Calder Hall and who continue the noble task of peaceful utilization of nuclear energy for the well-being of humanity.

In conclusion, I thank from my heart all those people and organizations who cordially received our delegation and showed us the most interesting objects in the field of power with so much hospitality. We shall remember Britain and her people with warm feelings.

CORRESPONDENCE

I.G.Y. PROGRESS REPORT

From W. T. J. ATKINS, B.SC.(ENG.), MEMBER*

READERS of the International Geophysical Year Progress Report which appeared in the June *Journal* (p. 311) may be interested to know that effects of some of the phenomena mentioned have recently been looked for—and found—in the somewhat improbable country of the British Grid transmission system. The straying of currents from the earth into communication circuits is *vieux jeu*, of course; indeed, the Society of Telegraph Engineers had strong words for it. Until recently, however, it had not occurred to anybody that the practice of multiple earthing of power circuits would be susceptible, though on a much lower scale of importance, to the same kind of 'interference'.

The currents need filtering to separate them from man-made alternating ones; but, once this is done, they show precise correlation with the current and magnetic-field records of geomagnetic observatories; and during the several months since the work was started, the charts obtained have sometimes evoked the envy of professional workers in that field.

An interesting feature of the records is that they reveal, superposed on the characteristic geomagnetic fluctuations, a smooth sinusoidal component due to the flow of tidal currents in the sea round the coasts. The magnitude of this component naturally diminishes with distance from the seaboard; but it is still just perceptible, at spring tides, even in the Midlands.

It should be added that, although peak currents in excess of a whole ampere have been measured in Grid circuits during magnetic storms, the most careful scrutiny of operational records has failed to trace any evidence that they have any influence on the working of the system.

* Mr. Atkins is with the Central Electricity Generating Board. His letter was received on the 30th June 1958.

GEORG SIMON OHM AND HIS LAW

From J. F. PERRIN, ASSOCIATE MEMBER

THE article by Mr. P. Hammond in the June *Journal* (p. 294) took me back to the famous discussion on Ohm's law between Prof. Silvanus P. Thompson (Principal of Finsbury Technical College) and Dr. R. T. Glazebrook (Director of the National Physical Laboratory) in the columns of the electrical Press during the winter of 1913–14. As this is probably known only to a few present-day members, it might be of interest to give a short account of the matter.

On the 27th November 1913, Mr. S. Evershed read his classic paper entitled *The Characteristics of Insulation Resistance** in which he states, under Summary and Conclusions, 'Conduction through absorbent insulation does not follow Ohm's law'. Prof. Silvanus P. Thompson, who opened the discussion, although full of praise for the paper, took Mr. Evershed to task for the notion that any substance did not obey Ohm's law. Thompson stated, 'Ohm's law is true under all circumstances for every kind of conductor, or insulator, or current, or anything else. It depends entirely on the definition of "resistance". I do not know any way of ascertaining the resistance of a body except by passing a current through it; the name "resistance" is given to the ratio between the electromotive force that is supplied and the current which results. That is Maxwell's definition. What Mr. Evershed undoubtedly meant, and what those people mean who say that something does not obey Ohm's law, is that the resistance is not constant. . . .'

Dr. R. T. Glazebrook, who presumably had not previously sent in his name requesting to take part in the discussion, was, in his own words, unable to squeeze a word in. Instead, a letter from him appeared in *The Electrician* for the 5th December 1913† in which he protested 'against Prof. S. P. Thompson's dangerous heresy with regard to Ohm's law. If all that Ohm had done had been to give a name to the ratio of the e.m.f. in a conductor to the current which is flowing, his own name would not have occupied the high position in our roll of great electricians which is justly now its due. Ohm showed, also, that for a large class of bodies this ratio is a constant so long as the physical conditions of the body remain the same, and it is this fact that gives the importance to the law.'

This brought a prompt rejoinder from Thompson in the following number of the same journal, and the correspondence proceeded for several weeks. Both quoted from a translation of Ohm's original writings but neither would give way, and the discussion ended with a rather devastating reply from Thompson in the number for the 16th January 1914.‡

* EVERSHED, S., *Journal I.E.E.*, 1914, 52, p. 51
† GLAZEBROOK, R. T., *The Electrician*, 1913, [ii], 72, p. 377
‡ THOMPSON, S. P., *The Electrician*, 1914, [ii], 72, p. 621

CORRESPONDENCE *(continued)*

This correspondence is interesting and well worth reading; one or two other people attempted to join in, but, strangely, none of the recognized authorities did so. Presumably, they did not want to get involved in a rather thorny subject.

From R. J. CARRIER, ASSOCIATE MEMBER

IN the article by P. Hammond in the June *Journal*, it is stated that Ohm was born in 1789 and implied that he died in 1849. I have always understood he was born in 1787 and died in 1854. A check in my dictionary confirms this.

Incidentally, Hammond's declaration 'in 1844 at the age of 60' does not line up with his own 1789 or my 1787 as Ohm's date of birth.

From P. HAMMOND, M.A., ASSOCIATE MEMBER*

I AM grateful to Mr. Carrier for pointing out a slip in my article. On p. 295, second column, fourth paragraph, the date 1844 should, of course, be 1849. Thus Ohm was born in 1789 and died in 1854. I have followed the dates given by Lommel in his edition of Ohm's collected papers. I was aware of the differing date of 1787 for Ohm's birth. This date is supported by the great authority of Sir Edmund Whittaker on p. 90 of Vol. 1 of his *History of the Theories of Aether and Electricity*. On the other hand, 1789 is supported by Prof. Howe in his editorial in *Wireless Engineer*, October 1947. He writes, 'Ohm was born . . . on the 16th March 1789, and not in 1781 as stated by Mr. Carter, nor in 1787, as stated in several encyclopaedias, including the *Britannica*'.

Perhaps one of your readers will visit the Continent this summer and could consult the parish records at Erlangen.

* Mr. Hammond is in the Department of Engineering, Cambridge University

A NEW EPICYCLIC DRIVE FOR ELECTRIC LOCOMOTIVES

From H. CHARNLEY, ASSOCIATE MEMBER

THE description by Mr. H. E. J. Symes† of the differentially driven electric locomotive is of great interest, and the mathematical analysis of its theoretical performance is impressive. I have, however, looked in vain for some performance figures actually obtained on test. These would be of more interest and use than the mathematics.

As the author points out, the only power to be obtained at the wheels is the differential of the power of the two motors. This is too small to make this method of drive practical. I was concerned during the recent war with a differential drive for a gun turret on a tank, using a type of control similar to that described by Mr. Symes. While we were able to swing the heavy turret round, the acceleration and deceleration were very poor. The experiments were abandoned because of the small power available. We considered a new control system obtaining the cumulative power of the two motors; but, as Mr. Symes says, it was more complicated and less smooth.

During the recent war, I suggested a differential system of controlling the two tracks of a tank. The two tracks were to be mechanically driven through a differential; but instead of mechanical brakes to slow down one track with respect to the other, two series-wound motors or generators were to be used.

A machine was to be coupled to each track through gearing, and would rotate on open-circuit during straight running of the vehicle. For turning, the machine coupled to the inside track would have its field reversed; and the two machines would be connected in series, with suitable resistors. The machine with its field reversed would act as a generator supplying current to the other machine, which would function as a motor. As the current would depend on the resistance in circuit, the amount of resistance cut out would determine the angle of turn. The general advantage of the method was that energy generated in slowing down one track would be used to speed up the other.

It should be stressed that the torques of the output (or input) shafts of a differential gear are always equal.

† 'The Principal Characteristics and General Analysis of a New Epicyclic Drive for Electric Locomotives', *Proceedings I.E.E.*, Paper No. 2556 U, April 1958 (105 A, p. 153) (A short review appeared in the April *Journal*, p. 189)

HISTORY OF ELECTRICAL ENGINEERING

From MAJOR L. H. PETER, M.C., A.F.C., MEMBER*

IN No. 8 of the series of articles on *The History of Electrical Engineering* (June *Journal*, p. 298), the author refers to 'George Westinghouse (1846–1914), famous as the inventor of the vacuum brake'. George Westinghouse was the inventor of the compressed-air brake and was a great opponent of the vacuum brake.

The full history of his achievements and 400 inventions will be found in *A Life of George Westinghouse*, written by H. G. Prout on behalf of The American Society of Mechanical Engineers and published by them in 1921.

* Major Peter is with the Westinghouse Brake and Signal Co. Ltd.

Forthcoming Events

ALL meetings are held at Savoy Place, beginning at 5.30 p.m. (tea at 5 p.m.), except where otherwise stated. The nature of the meeting is indicated by the following key:

M MEASUREMENT AND CONTROL SECTION
O ORDINARY
R RADIO AND TELECOMMUNICATION SECTION
S SUPPLY SECTION
U UTILIZATION SECTION

September 1958

S **18–21** *Thursday–Sunday* Section Visit to Edinburgh

October

O **9** *Thursday* S. E. GOODALL, M.SC.(ENG.) Inaugural Address as President‡

M **14** *Tuesday* J. K. WEBB, M.SC.(ENG.), B.SC.TECH. Chairman's Address‡

U **16** *Thursday* R. A. MARRYAT, B.SC.(ENG.) Chairman's Address‡

R **22** *Wednesday* G. MILLINGTON, M.A., B.SC. Chairman's Address‡

S **29** *Wednesday* D. P. SAYERS, B.SC. Chairman's Address‡

‡ No advance information will be available

This is not the complete list of meetings to be held at Savoy Place during October

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Producing and Using High Test Voltages

In the range where high voltages are directly employed by the physicist and the engineer, the highest voltage attained (about 10 MV) appears to be about one order of magnitude lower than the estimated voltage of the lightning flash.

In this article, based on his Chairman's Address to the North Western Centre on the 1st October 1957, the author indicates the types of high test voltage that are of interest to research or development electrical engineers, shows how these voltages are produced, and discusses the orders of voltage magnitude that are needed. Present-day requirements are compared with those considered satisfactory 30 years ago. Mr. Perry is in the Research Department of Metropolitan-Vickers Electrical Co. Ltd.

F. R. PERRY, M.SC.TECH., MEMBER

IN THE industrial high-voltage laboratory which I joined in 1927, the main items of high-voltage gear available were:

(1) A 500 kV r.m.s. 50 c/s transformer

(2) A Tesla transformer giving a damped high-frequency discharge of about 500 kV peak at 100 kc/s

(3) A Wimshurst machine giving direct voltages up to perhaps 50–70 kV.

There were, of course, a number of other power-frequency testing transformers of lower voltages, but the items mentioned were the largest units for dealing with (*a*) power-frequency voltages, (*b*) transient high-frequency voltages, and (*c*) direct voltages.

The rest of the historical picture is as follows. In 1922, Dessauer patented his method of producing high power-frequency voltages by connecting two or more transformers in cascade, and in 1923 Marx patented his multi-stage circuit for the production of high impulse voltages. This latter invention, and the realization that lightning voltages are unidirectional rather than high-frequency phenomena, led to a change of emphasis, so that Tesla transformers as sources of transient voltages were gradually superseded by impulse generators.

To-day, the voltages of main interest are power-frequency and impulse voltages. Damped high-frequency voltages, as produced by a Tesla transformer, are now mostly used for testing porcelain insulators.

High direct voltages have always had special applications, e.g. for the site testing of high-voltage cables, but they will be more widely needed as the use of high-voltage direct current for power transmission increases.

Why High Test Voltages?

High power-frequency voltages and impulse voltages are required by the electrical engineer for two reasons:

(1) To test manufactured high-voltage equipment such as transformers, bushings, air-blast and oil circuit-breakers, insulators, etc. The tests may be merely of the withstand type or they may involve the measurement of the flashover voltage of the equipment in question.

(2) To obtain design data concerning the breakdown of air-gaps, oil-gaps, solid insulation, etc., so that design engineers have information in advance of their immediate requirements and also can estimate what margin of safety exists in their designs of high-voltage equipment. This second need requires higher voltages than the first.

In either case, the voltages needed are related to the operating voltage of the system for which the high-voltage gear is being built. To determine what magnitude of test voltages may be required during a future period of years, it is necessary to try to foresee what magnitude of transmission voltages is likely to be reached during the same period.

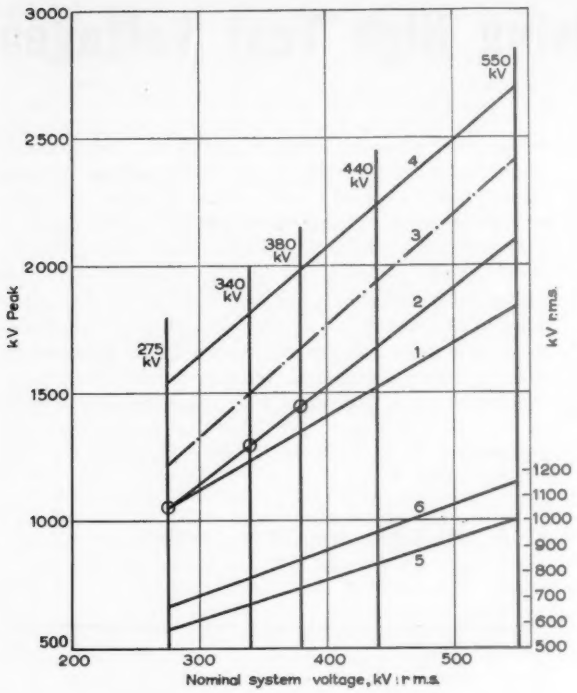
An attempt was made by me about two years ago to predict the trend in transmission voltages; and Table 1 suggests how transmission voltages might be expected to increase in the next few years in areas, at home or abroad, accessible to British manufacturers. It is necessary to make this qualification because, for example, the Swedish 380 kV line began operating in 1952, and a 340 kV line is already operating in America.

Table 1. Probable increase in system voltages

Nominal system voltage, kV r.m.s.	Year of operation
275	1953
340	1958
380	1958–59
(440)	1963
(550)	1968

The first three system voltages listed are already in being in various parts of the world. The others are speculative, and their adoption might well be affected by two factors: (*a*) the advent of nuclear energy and (*b*) more extensive development of d.c. transmission.

On the assumption, however, that a 550 kV a.c. system is at least within the bounds of possibility, it becomes feasible to estimate the voltages, alternating and impulse, which might be needed to carry out the necessary design tests in the development of suitable high-voltage gear.



1 *Magnitude of impulse and alternating test voltages required in future*

1 Full-wave impulse test: transformers
2 Full-wave impulse test: air-blast circuit-breakers
3 Probable impulse flashover: air-blast circuit-breakers
4 Front-of-wave impulse test: transformers
5 Suggested 1 min a.c. test } bushings
6 Suggested puncture test }

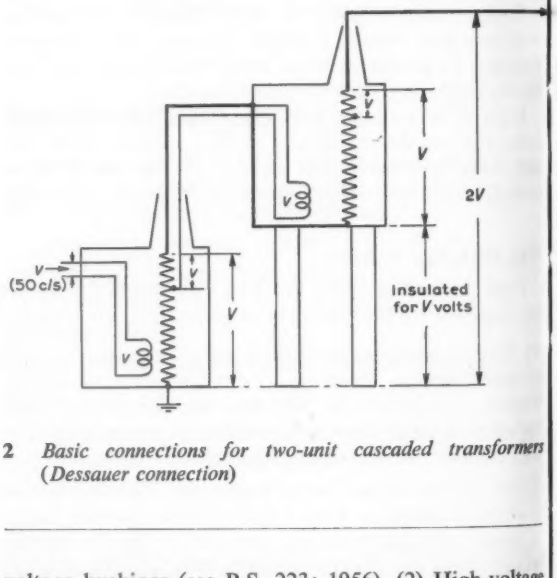
Magnitude of Impulse Voltages Required

One difficulty in estimating the value of the impulse voltages required arises because insulation levels are still being discussed for systems operating at 380 kV nominal. Originally it appeared that a value of 1·35 MV peak might be used for the full-wave impulse test on transformers, and curve 1 of Fig. 1 was produced on this basis. On the other hand, an impulse-withstand voltage of 1·45 MV peak has been specified for air-blast circuit-breakers (curve 2). The latest discussions indicate that an impulse level of 1·425 MV peak will be established, and the final curve may be between curves 1 and 2. Curve 3 is based on values 15% higher than in curve 2 and represents the probable impulse-flashover voltages of air-blast circuit-breakers. Curve 4 is based on the specification of the American National Electrical Manufacturers Association for the front-of-wave test on transformers in which the impulse-voltage wave is chopped on the wavefront at a specified minimum value. For a 230 kV system, the specified (American) full-wave impulse-test value is 1050 kV peak, and the minimum peak value of the voltage to be attained in the front-of-wave test is 1·4 MV. This would require a prospective voltage from the impulse generator at least 10% higher (= 1·54 MV), which is equivalent to 1·47 times the value of the full-wave impulse-test voltage (1·050 MV peak). These values would be appropriate to an effectively earthed 275 kV system, and curve 4 is drawn with 1·54 MV as a starting-point.

For a 550 kV system, therefore, the front-of-wave impulse test on a transformer might require a prospective output voltage from the generator of 2·7 MV. If a margin of 30% is allowed for the provision of design data and a further 30% for the 'regulation' of the impulse generator between open-circuit and load conditions, then the nominal output of the generator should be 4·5 MV, which confirms the present trend of building generators in the range of 3–5 MV.

Magnitude of Power-Frequency Voltages Required

The estimation of the probable power-frequency voltages required is affected by two factors: (1) For impulse-voltage-withstand tests on transformers it is now generally agreed that an effectively earthed system can have a reduced insulation level which is one class lower than that of a non-effectively earthed system of the same nominal voltage. This principle has now been accepted with respect to power-frequency tests on high-voltage bushings (see B.S. 223: 1956). (2) High-voltage bushings are subjected to a 1 min alternating-voltage-withstand test in air and may also be subjected to an alternating-voltage puncture test in which the bushing is totally immersed in oil. This latter is now only required as a type test on bushings which are not impulse-tested.



2 *Basic connections for two-unit cascaded transformers (Dessauer connection)*

For effectively earthed systems of 275 kV and upwards,

Table 2. Details of size of building and equipment in various high-voltage laboratories

Laboratory	Size of building	High-voltage transformers		Impulse generator			
		No. of units and kV r.m.s./unit	Total voltage kV r.m.s.	Output voltage, kV peak	Charging voltage, kV (direct)	No. of stages	Discharge energy, kWs
1 Electrical manufacturer, Pittsfield, U.S.A. ..	165 ft × 95 ft × 75 ft high	5 × 350	1750	5100	300	17	84
2 Porcelain manufacturer, Barberton, U.S.A. ..	—	—	—	(2 equipments of this size) 3000	—	—	36
3 Electrical manufacturer, Hollinwood, England	—	—	—	4000	220	18	285
4 National Physical Lab., Teddington	120 ft × 60 ft × 45 ft high	1 × 1000 (open air)	1000	3200†	400	8	77
5 Glass manufacturer, St. Helens, England ..	120 ft × 80 ft × 60 ft high	2 × 650	1300	2330	167	14	29
6 Electrical manufacturer, Lyons, France ..	118 ft × 36 ft × 56 ft high	2 × 750	1500	2500	125	20	9
7 Électricité de France, Paris	145 ft × 72 ft × 72 ft high	1 × 1000	1000	3500	250	14	80
8 Porcelain manufacturer, Tarbes, France ..	168 ft × 80 ft × 85 ft high	1 × 500	500	5500	344	16	60
9 Electrical manufacturer, Berlin	79 ft × 66 ft × 69 ft high	2 × 500	1000	2700	300	9	162
10 Electrical manufacturer, Nuremberg	Open-air lab.	2 × 800	1600 (open air)	3600 (open air)	200	18	50
11 High-voltage laboratory, Moscow	223 ft × 105 ft × 105 ft high	3 × 750	2250*	7200*	300	24	430
12 Electrical manufacturer, Ludvika, Sweden ..	—	—	—	3600	—	—	91
13 Electrical manufacturer, Baden, Switzerland	100 ft × 80 ft × 50 ft high	1 × 1200 1 × 400	1600	2400	—	—	25
14 Institute of Science, Bangalore, India ..	120 ft × 85 ft × 93 ft high	3 × 350	1050	3000	300	10	50

* It is not known whether these units have yet been installed
† Floor of laboratory lowered by 8ft to give sufficient clearance to ceiling

it can be assumed that reduced test levels will be accepted for bushings. The 1 min alternating-test voltage is 575 kV r.m.s. and the puncture-test voltage is 660 kV r.m.s. for bushings used on an effectively earthed 275 kV system. Curves 5 and 6 of Fig. 1 are drawn from these respective starting points. For a 550 kV system, therefore, a test voltage of 1·15 MV r.m.s. might be required for the puncture test on a bushing; if a 30% margin for design purposes is allowed, a testing transformer to give 1·5 MV r.m.s. will be needed. If, however, the puncture test is replaced by an impulse test and the only high-alternating-voltage test on a bushing is the 1 min withstand test in air, then at a voltage of 1 MV r.m.s. a testing transformer of 1·3 MV r.m.s. output will give the suggested 30% margin. On the other hand, existing 1 MV transformers might just be adequate to carry out the necessary tests, if the margin for design purposes were dispensed with.

Making High Power-Frequency Voltages

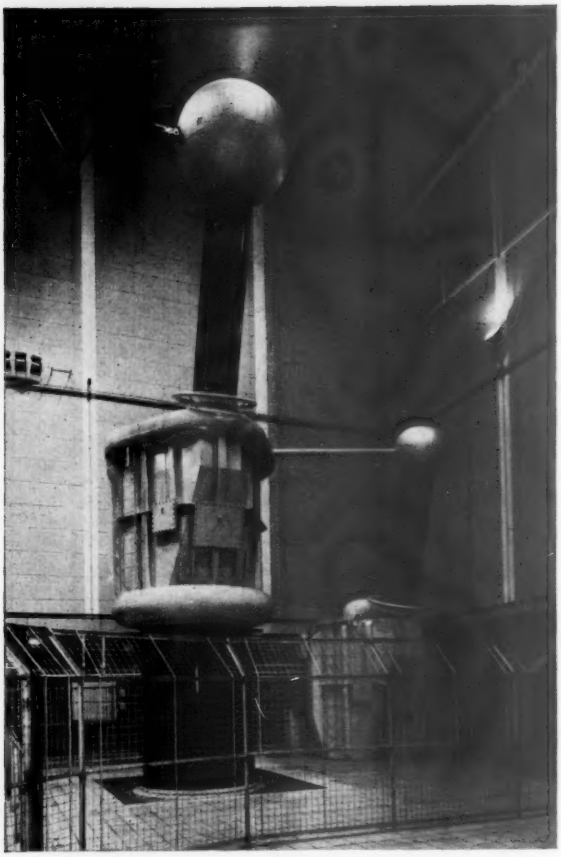
We turn now to the study of equipment capable of producing 1 MV r.m.s. or more at power frequencies.

From 1922 to 1930 a number of single-unit 1 MV testing transformers were built in various countries, but not all of these were completely successful. The Dessauer method of connecting multiple-unit transformers in cascade was, however, quickly shown to be a satisfactory and certain way of producing 1 MV r.m.s., and, in general, this means has been adopted for all later installations for producing voltages higher than 1 MV.

The basic diagram of connections is given in Fig. 2 for two transformers, each of ratio V/v volts, connected in cascade to give a voltage of $2V$ volts to earth from a primary voltage v. The same basic method can be, and has been, used to cascade 3-, 4- or 5-unit transformers to give output voltages three, four or five times that from a single unit.

Table 2 gives details of power-frequency- and impulse-voltage equipment in various high-voltage laboratories. The list is not intended to be exhaustive and is confined to laboratories equipped either with impulse generators capable of delivering 3 MV peak or more, or with power-frequency transformers for producing 1 MV r.m.s. or more. Some of the laboratories listed satisfy both these conditions.

The highest voltage developed by a single unit is 1·2 MV r.m.s. (laboratory 13), but it is believed that this is a nominal rather than a realistic output. Two cases are given of single units developing 1 MV r.m.s. Sizes of the individual units in cascade equipment range from 350 kV r.m.s. (five in cascade in laboratory 1) to 800 kV r.m.s. (two in cascade in laboratory 10). The highest alternating-voltage equipment is that of laboratory 11 (3 × 750 kV r.m.s.). The building was completed



3 *Two 650 kV r.m.s. transformers in cascade*

in 1957, and it is assumed that this equipment has been installed by now.

Fig. 3 shows the two 650 kV r.m.s. units, cascade-connected, of laboratory 5.

Producing Damped High-Frequency Voltages

The interest in this form of high voltage is mainly historic, though damped high-frequency voltages are still used by porcelain manufacturers for certain tests. Many high-voltage laboratories during the years 1929 to 1931 were being equipped with Tesla transformers, the range of voltages available being from about 0·75 to 1·5 MV peak.

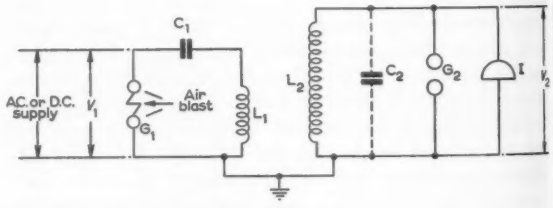
The basic circuit for the generation of such voltages is given in Fig. 4. The primary circuit of the Tesla transformer C_1 L_1 is charged from either a d.c. or an a.c. source until the spark-gap G_1 breaks down. The circuit G_1 C_1 L_1 is oscillatory; and the energy initially stored in the primary circuit is gradually transferred to the secondary circuit L_2 C_2, which is tuned to approximately the same frequency. C_2 in the high-voltage circuit represents the total secondary capacitance, including the self-capacitance of the high-voltage winding and the capacitances of the measuring sphere-gap G_2 and of the load I. Transfer of energy back to the primary circuit is prevented by means of the air blast across the primary gap G, which interrupts the spark when the oscillations in the primary are at a minimum amplitude. The primary circuit is effectively detuned in this way, and the energy is retained and finally dissipated in the secondary circuit including the test object.

The frequency of oscillations for which Tesla transformers were usually designed ranged from about 50 kc/s to 200 kc/s. The shape and duration of the damped-wave-train pulses generated were liable to vary according to the type of equipment under test, and for that reason it was difficult to obtain repeatable results with this form of high voltage.

It was realized, however, that the over-voltages caused by lightning were more severe than those caused by switching surges, which resembled to some extent the damped oscillatory waves produced by Tesla transformers. Hence, the multi-stage impulse generator gradually superseded the Tesla transformer as a means of determining the behaviour of high-voltage equipment in transient conditions.

Production of High Impulse Voltages

The important feature of the Marx circuit for generating impulse voltages was its method of charging a number of condenser units in parallel and then automatically discharging them in series by the breakdown of suitably connected sphere-gaps. By this means, high-voltage impulses could be obtained economically, using capacitance and resistance units of much lower voltage-rating. Fig. 5 illustrates by heavy lines the operation of the impulse-generator circuit in (*a*) charging and (*b*) discharging conditions. For simplicity, a four-stage circuit is shown, but the circuit can be extended to a large number (20–50) of stages if desired. A number of impulse generators developing 1–2 MV were being

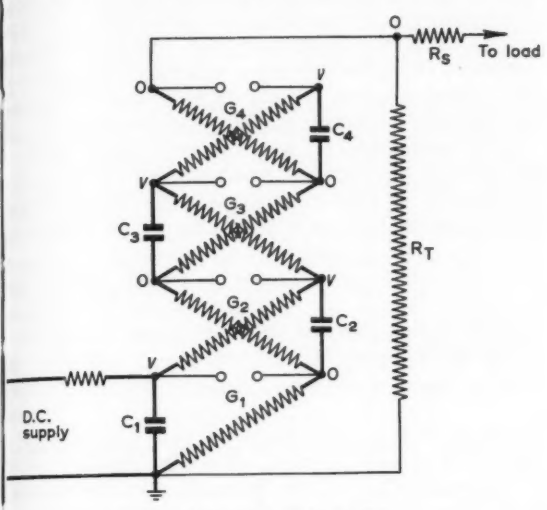


4 *Connections of Tesla transformer*

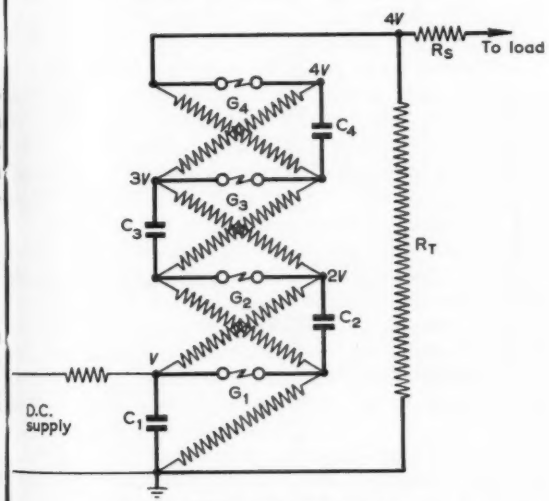
$$C_1L_1 \simeq C_2L_2 \frac{V_2}{V_1} = M\sqrt{\frac{C_1}{C_2}}$$

where $M < 1$ (efficiency of transformation)

built about 1929–31, using circuits identical or at least similar to those put forward by Marx; but F. W. Peek, Jnr.,[1] was producing 5 MV impulses in 1929, using a four-stage circuit charged from an alternating-voltage



a Charging condensers in parallel



b Discharging condensers in series

5 *Principle of operation of four-stage Marx impulse generator*
C_1, C_2, C_3 and C_4 stage capacitors
G_1, G_2, G_3 and G_4 interstage spark-gaps

source. This generator was eventually replaced by one of more conventional design, using direct-voltage charging for a larger number of lower-voltage stages.

In the 1930's the range of impulse voltages available was generally from 2 to 3 MV, except at the General Electric Laboratory at Pittsfield, where two nominally 5 MV generators of opposite polarity could be used to produce a 10 MV discharge across a 30 ft gap between pointed brass electrodes.

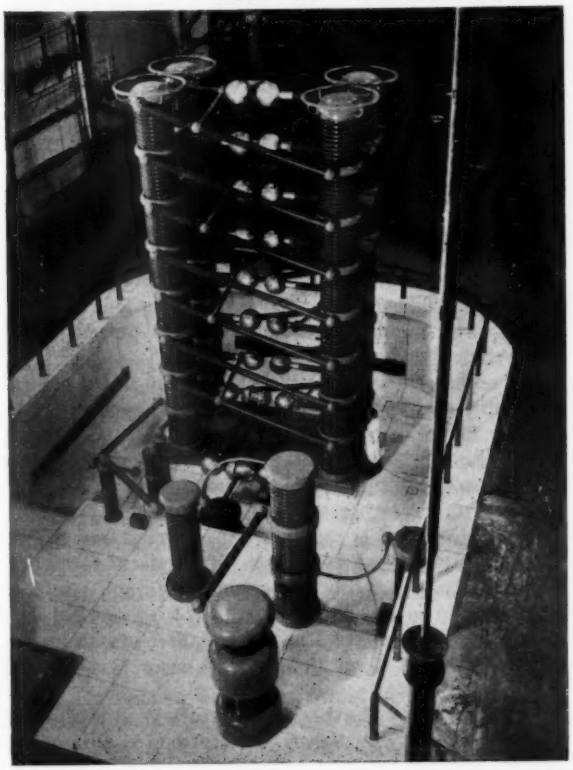
At the present time, the tendency is to build impulse generators in the 3–7 MV range. Table 2 gives details of a number of impulse generators, mainly developing 3 MV peak or more, in various laboratories throughout the world. The variety of designs is illustrated by the range of direct charging voltages (125–400 kV), of the number of stages (8–24), and of the discharge energy (9–430 kWs). The trend towards higher output voltages means that the values of discharge energy are also increasing; but in addition there is a need for higher discharge-capacitances, which again tends to enhance the energy storage of modern generators.

The two 5·1 MV peak generators of laboratory 1 enable a discharge at 10 MV ($\pm$5 MV to earth) to be obtained. The largest single unit listed (7·2 MV) is that installed in laboratory 11. Fig. 6 depicts an eight-stage 3·2 MV peak generator.

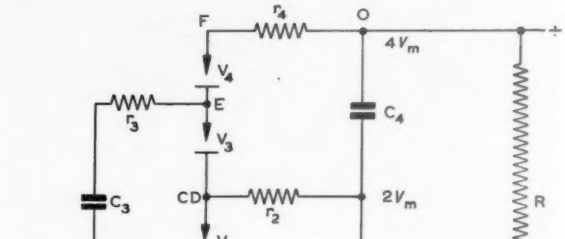
Developing High Direct Voltages

As a matter of historic interest, it may be noted that the earliest devices for developing high voltages, i.e. of the order of a few kilovolts up to a few tens of kilovolts,

6 *Eight-stage 3·2 MV peak impulse generator with charging equipment in foreground*
By courtesy of the National Physical Laboratory



were various forms of electrostatic machines which delivered high direct voltages. The transformer, however, became a much more convenient and efficient means of developing high alternating voltages, with the added merit that it was a static device involving no moving parts.



7 *Connections of a two-stage (four-valve) cascade d.c. generator: Cockcroft and Walton circuit*

V_1–V_4 Rectifying valves
C_1–C_4 Capacitors (C_1 is rated for half the voltage of C_2–C_4)
r_1–r_4 Limiting resistors
R Load resistor
T Transformer
V_m Peak voltage from transformer

Nevertheless, a need soon arose for high direct voltages for various applications, e.g. site testing of cables; accelerating voltage for cathode-ray tubes; charging voltage for impulse generators; etc. The basic way of obtaining such voltages was by rectifying the voltage from a suitable h.v. transformer with a mechanical, thermionic or metal rectifier.

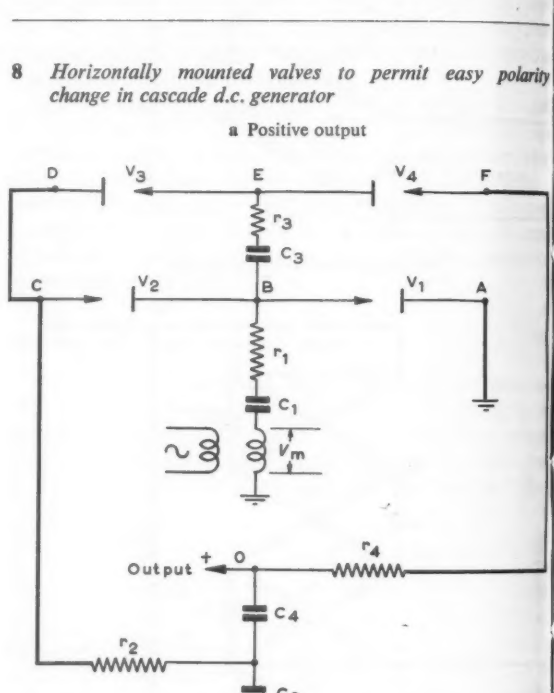
Table 2 shows that direct voltages ranging from about 125 to 400 kV have been used for the charging of large high-voltage impulse generators, and the site testing of cables has involved voltages of about the same range. Up to about 200 kV, a simple form of full-wave rectifier is suitable for producing direct voltages; and for lower voltages half-wave rectification may be adequate. Above 200 kV direct, however, it is more convenient to use some form of multi-unit circuit; and although Cockcroft and Walton[2] were not the first to adopt this principle, their version was a marked improvement on earlier schemes and is representative of modern forms of cascaded d.c. generator. For engineering applications it is essential to be able to change readily from one polarity to the other, and what follows refers, therefore, to equipment which has been designed to meet this specific requirement.

Fig. 7 presents the basic Cockcroft–Walton circuit, using four rectifying valves V_1–V_4 to give a nominal output of $4V_m$, where V_m is the peak output voltage of the transformer T. If the rectifier valves are of the continuously evacuated type, they can be mounted conveniently in a single column one above another and with the pumping unit located at the base of the stack. The resistors r_1–r_4 are designed to limit any fault currents arising from short-circuits or back flashover inside the rectifiers. The main objections to vertical disposition of the rectifying valves are the large over-all height and the difficulty of quickly changing the polarity.

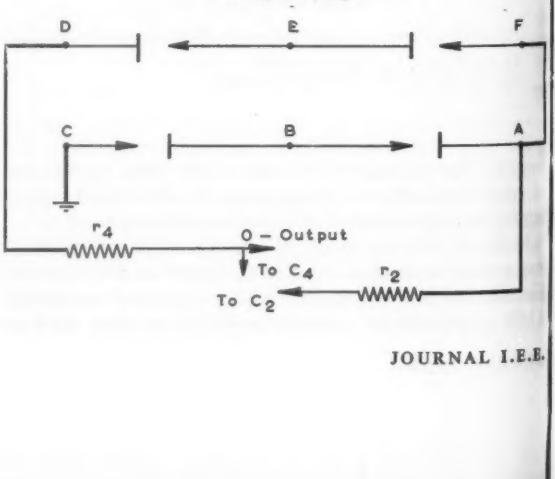
These two objections were overcome in an apparatus designed by Waterton, in which the valves were placed horizontally in pairs at different levels. The scheme of this apparatus is shown in Fig. 8. Fig. 8*a* gives the circuit

8 *Horizontally mounted valves to permit easy polarity change in cascade d.c. generator*

a Positive output



b Negative output



for positive-polarity output. Valves V_1 and V_2 are mounted horizontally, in line, on either side of the vertical pumping column (not shown) which also supports valves V_3 and V_4 at a higher level. The output is taken from point O at the top of the capacitor column C_4 C_2, which is fed from point F via a busbar resistor r_4. (The lettered points of the circuit are identical to those of Fig. 7.)

Fig. 8*b*, for simplicity, gives only those circuit connections which have been changed in order to provide negative-polarity output at point O, which is now connected by r_4 to D. The polarity change can be effected simply by changing four busbar connections. A generator to develop a direct voltage of 500 kV has been successfully built on this principle, using four continuously evacuated rectifying valves with porcelain envelopes. Filament heating for the valves is obtained by means of small generators mounted on insulating columns and driven by insulating belts from standard motors, located at the earthed end of each column.

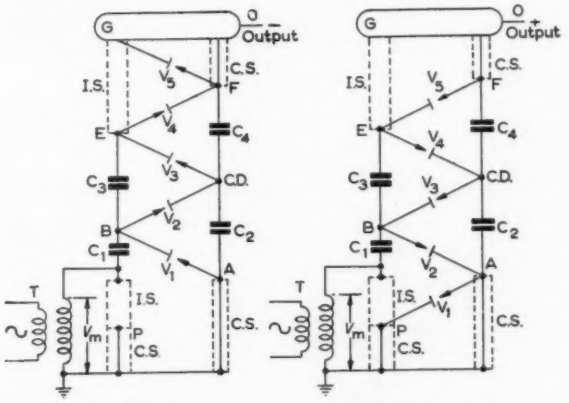
From purely electrical considerations it is clear that more rectifying stages could be added in a similar manner; but the mechanical problem of supporting the rather heavily constructed rectifying valves would become difficult, and the number of connecting links to be changed individually would be increased in number proportionately. By using high-voltage metal rectifiers, however, Waterton[3] showed that it was possible to use the rectifier units themselves as the movable links by which the polarity could be changed. This is illustrated in Fig. 9, giving the connections required for (*a*) negative output and (*b*) positive output. The number of rectifiers needed is one more than in the conventional circuit. This is purely for mechanical reasons, so that all the rectifier units can be mechanically linked and the polarity change made in one operation. A million-volt generator (d.c.) based on this design could consist of seven stages rated at 150 kV per stage. This would involve 14(+ 1) rectifiers in series, each rated for 75 kV forward voltage (= 150 kV reverse peak). To improve the regulation of such an equipment with a given size of capacitor, a 200 c/s supply would be used.

So far, the engineering demand for this type of equipment has been much more restricted than for similar apparatus for physical research. If, however, direct-voltage transmission at 500–800 kV becomes a practical proposition, then test equipment in the 1–2 MV range will be needed in high-voltage engineering laboratories.

Comparison with Voltages Occurring in Nature

In fine weather there is a fairly steady electric field in the air, with an average value of about 100 volts/m. The gradient varies from time to time and can be modified by the weather or by special atmospheric conditions such as industrial pollution. This electric field is positive, i.e. the earth is at a negative potential with respect to the atmosphere; and the total potential between the earth and somewhere in the ionosphere (about 60 miles up) has been estimated to be about 290 kV.

In disturbed weather, the picture is quite different. The thundercloud is a large-scale frictional generator in which ice crystals, in falling against the upward air currents, are charged negatively while the air carried to the top of the cloud is charged positively. Somewhere near the base of the cloud there may be localized positive charges which are generated by the breaking up of raindrops falling against the upward air stream. The positive charge is located near the lower level, where the cloud temperature is above freezing point. A charged thundercloud causes enhanced field gradients of the order of 35 kV/m at the earth's surface in its neighbourhood, but in addition it is a source of large-scale impulse discharges, i.e. lightning flashes to earth or between clouds.



9 *Modified multi-stage cascade d.c. generator, using metal rectifiers as switch links for changing polarity*

V_1–V_5 h.v. metal rectifiers
C.S. Conducting supports
I.S. Insulating supports

It is clearly impossible to measure directly the voltage involved in a lightning flash. However, measurements have been made of the electrostatic-field changes due to lightning flashes at various distances by C. T. R. Wilson initially and later by other observers. From these measurements it is possible to estimate the total amount of charge in a thundercloud and the height of the charge above ground level. In order to calculate the potential of the thundercloud it is necessary to assume a value for the volume of the charged portion of the cloud.

Wilson estimated that the average charge on a thundercloud was 20 C, located at a height of 2 km and concentrated in a sphere of about 400 m radius. On this basis, the voltage developed would be of the order of at least 1000 MV and might be as high as 6000 MV for highly charged clouds. Bruce and Golde,[4] on the other

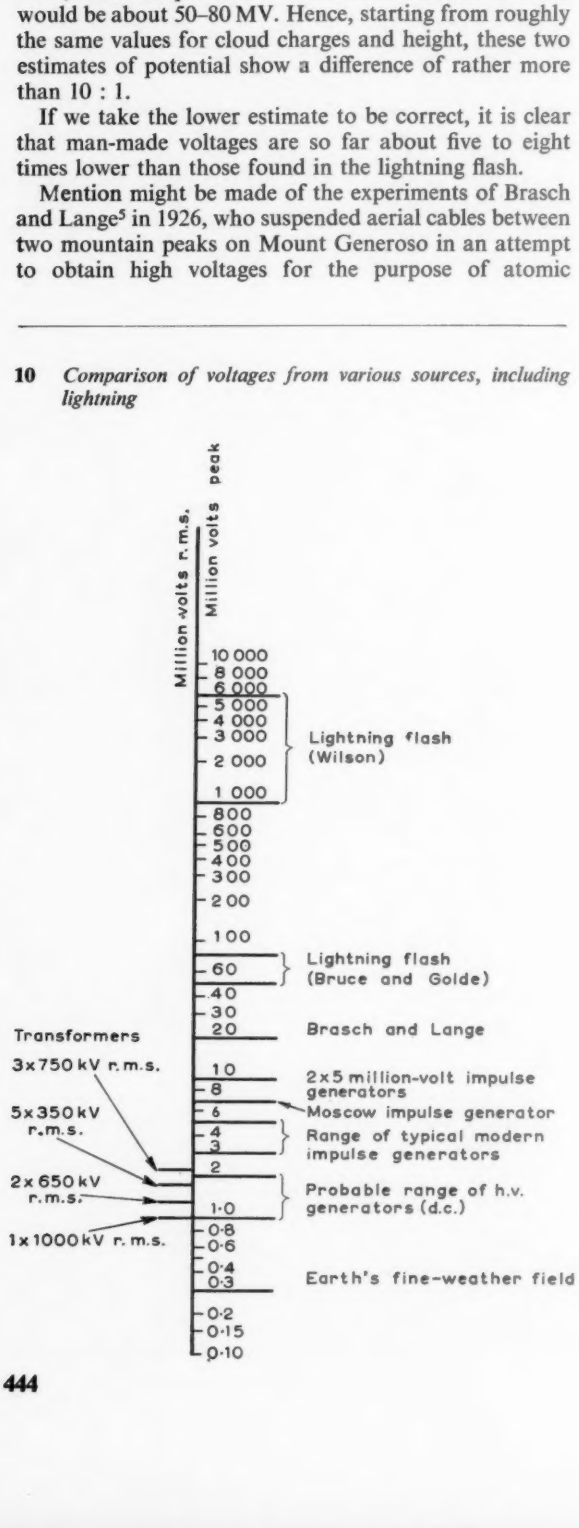
hand, suggest that the charge involved may be 30 C, located at a height of 2·5 km. They point out that a lightning flash consists, on an average, of three separate strokes, which suggests that the total charge is dispersed fairly widely in the cloud over an area of, say, 100 km^2. If so, then the potential of the cloud relative to earth would be about 50–80 MV. Hence, starting from roughly the same values for cloud charges and height, these two estimates of potential show a difference of rather more than 10 : 1.

If we take the lower estimate to be correct, it is clear that man-made voltages are so far about five to eight times lower than those found in the lightning flash.

Mention might be made of the experiments of Brasch and Lange[5] in 1926, who suspended aerial cables between two mountain peaks on Mount Generoso in an attempt to obtain high voltages for the purpose of atomic research. Thunderstorms and lightning discharges were of frequent occurrence in the neighbourhood, and they succeeded in obtaining short-time pulses of up to 20 MV peak. However, the source of supply was probably too erratic to make systematic investigation possible, and these workers later developed more-conventional forms of impulse-voltage generator for their work.

By using a vertical logarithmic scale it is possible to show the relation between the various voltage magnitudes discussed and relate them to the estimates of the voltage of the lightning flash (Fig. 10). The voltages produced by power-frequency testing transformers are given in r.m.s. values. Their peak values would be 40% higher. Thus the 3 × 750 kV transformers (= 2·25 MV r.m.s.) would give a peak voltage of 3·2 MV.

10 *Comparison of voltages from various sources, including lightning*



Summary

I have reviewed the use made by electrical engineers of various forms of high test voltage and the range of voltage employed. As these voltages are generally wanted for tests in air at atmospheric pressure, large clearances are needed; and unless the equipment is located in the open the buildings required to house the high-voltage generators are of large dimensions, as shown by the examples in Table 2.

The use by physicists of high voltages for particle acceleration generally involves a range of voltage similar to that discussed; and, at various times, all these types of voltage have been employed in particle accelerators. It is usually easier, however, for the physicist to integrate the accelerator tube (equivalent to the test object of the engineer) with the high-voltage generator, and this leads to combined equipment which can either be immersed in oil or insulated with compressed gas of high breakdown strength. In either case, very much more compact equipment for a given voltage is available to physicists, e.g. the Van de Graaff generator for producing high direct voltages, or the resonant transformer for high alternating voltages.

However, when the physicist is interested in very-high-energy particles, i.e. of above a few million electron-volts, he finds it more convenient to use indirect means of acceleration, such as magnetic induction or radio-frequency electromagnetic fields. Devices such as betatrons, synchrotrons, cyclotrons and linear accelerators are employed for the production of these high-energy particles.

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THE BRITISH ELECTRICAL CONFERENCE AT BRUSSELS

THE organizers of the British Electrical Conference had a happy thought when they chose Brussels on the 16th May as the meeting-place for 1958. The Universal Exhibition had been open for a month and was thus in full swing, and those attending the conference could combine a visit to the exhibition with their other activities. Besides this, a conference 'starring' two such eminent men of science as Sir Gordon Radley (Immediate Past-President of our Institution) and Sir John Cockcroft, each describing famous British achievements, was a fillip to the already impressive display of British technology in the Fair itself.

The proceedings were opened by the President of the conference, Sir Vincent de Ferranti (another Past-President of The Institution), in the elegant Petit Auditorium on the exhibition site on Friday morning, the 16th May. Sir Vincent's short speech of welcome and introduction was followed by the first paper, *Communication between Nations and Peoples*, by Sir Gordon Radley.

Sir Gordon reviewed the recent developments in high-frequency techniques for providing many telephone channels over a single pair of conductors and also the progress made in electronic switching. 'The whole objective of contemporary research in communication', said Sir Gordon, 'is to enable a call to be made from any telephone to any other telephone quickly, easily and at a reasonable cost. . . . By 1970 three-quarters of all long-distance calls in the United Kingdom should be dialled by the callers, and plans for international subscriber dialling are being made.'

He went on to describe the development of coaxial tubes which provide several hundred speech channels, and the supplementary microwave radio relay systems; and he stressed that such systems must be capable of transmitting colour television.

Transatlantic Cable

Sir Gordon then devoted the remainder of his paper to the most stimulating achievement in communication in recent times—the transatlantic telephone cable, in the planning of which he himself played an important part, and which he described in his Presidential Address to The Institution.*

The speech channels in the first transatlantic telephone cable are spaced 4 kc/s apart, but Sir Gordon said that British engineers had recently designed a terminal channel filter equipment giving practically the same quality of speech transmission with channels only 3 kc/s apart. This means a potential increase in traffic capacity of future cables of 33%.

Future Cables

Because of the increase in telephone traffic between Europe and North America since the transatlantic cable was laid, a second cable system of the same type is planned for 1959, with an eastern landing in France.

Sir Gordon added: 'For 1960 Britain and Canada plan a cable which will be a distinct technical advance on the first two transatlantic systems. There will be a single cable providing "go" and "return" speech channels for 60 telephone circuits. Ninety both-way repeaters will be required between Newfoundland and Scotland. These will be accommodated in fairly large rigid steel housings. Means for handling these

Sir Vincent de Ferranti opens the conference

l. to r.: Sir Hugh Beaver, Sir Vincent de Ferranti, Sir John Balfour (U.K. Commissioner-General), and Mr. D. Maxwell Buist (Chairman of the organizing committee of the conference)

housings as part of a continuous cable-laying operation were successfully tried out at sea during February 1958. A new type of deep-sea coaxial cable was also successfully tried. This cable, which is a British development, has a torsionally balanced strength member at the centre of the inner conductor but is without the usual outer steel armouring, unwanted for protection at great depths. It handles much more easily than armoured cable and shows no tendency to kink. If it is as successful as appears likely, the conventional armoured cable will become obsolescent for deep-sea work.

'The new Canadian cable will transmit a frequency bandwidth of more than 500 k/cs. This is a remarkable increase from the 100 c/s which was the maximum frequency transmitted across the Atlantic by cable before 1956. Use of transistors will ease the problem of power supply to the repeaters. More repeaters will be possible, and a transatlantic cable with sufficient frequency bandwidth for television will become a technical possibility within the next decade.'

After an interval for coffee in the adjoining bar, Sir Gordon introduced an excellent film which showed the laying of the transatlantic telephone cable.

The Battle of the Alouette

Luncheon was served in the Alouette restaurant in the Canada pavilion, whither the conference members and their ladies were conveyed through the rain in one of the quaint bus-trains used at the fair. The luncheon was served buffet style, and, with over 400 people present in the smallish restaurant, it was only with some difficulty that one reached the buffet tables, behind which the waiters stood entrenched, with the anxious eyes of beleaguered men. The rewards for the struggle were, however, delicious.

The afternoon was free for conference members to see the sights of the exhibition itself, though it would require a week of arduous exploration to cover the whole exhibition with the attention it deserves.

Saturday morning, which was fair and sunny, was also left free for visiting the exhibition, and it was not until 3 o'clock that members gathered once more in the Petit

* 'Communication—at Home and Oversea', *Journal*, January 1957, p. 2

Auditorium to hear Sir John Cockcroft, a Faraday Medallist of our Institution, deliver his paper, *Nuclear Energy—the Power of the Future*. The first part of the paper was an account of Britain's first two years' operating experience on Calder Hall.

It had been found that the designed output figure of 75 MW had been conservative and that 10% greater output could be comfortably achieved. The flexibility of operation was an important characteristic; the usual operational rate of increase of power level was 5 MW per minute, so that it was possible to increase the load from 30 MW to 180 MW in half an hour—as fast as in a conventional power station.

Overcoming Creep and Stored Energy

Important facts had been discovered, both at Harwell and at Calder Hall, about the behaviour of fuel elements. Irradiation of uranium can produce creep at 100 times lower stresses than are normally required, and since, in the Calder Hall reactors, six fuel elements were originally stacked vertically one above the other in each channel, the bottom elements were heavily loaded. To obviate this, additional central supports for the fuel elements had been provided. In future designs, the weight of each fuel element would be taken by the graphite.

Useful experience had been accumulated on the rate at which energy was stored in graphite by the displacement of atoms from their normal positions. 'The present indications are', said Sir John, 'that it will be three to five years before the stored energy reaches a level at which it will be advisable to anneal the graphite to release this energy. . . . The Calder Hall design provides for raising the temperature of the graphite by recirculating part of the CO_2 without its passing through the heat exchanger. This will allow the energy to be released under conditions of coolant flow, which would make any excessive temperature rise impossible. . . . We do not think that the stored energy presents any problem in Calder Hall.'

Engineering Progress

Sir John proceeded to describe the advances that had been made in welding techniques (which permit higher gas pressures), in obtaining higher operating temperatures of the fuel elements, and in improving the heat-transfer surfaces. These factors have all combined to increase by many times the output of Calder-Hall-type stations. At Hinkley Point the net designed electrical output has been raised to 500 MW, which has reduced the estimated capital costs by about 20%. Industrial organizations have said that outputs of 800 MW are possible by means of straightforward engineering developments, and this should lead to a further fall in capital costs of about 10%. When Hinkley Point is commissioned in 1962 the cost of nuclear power in Britain should break even with the cost of power from coal-fired stations, and thereafter is likely to be lower.

The cocktail reception in the Palais de l'Elégance

At the cocktail reception

l. to r.: Sir John Cockcroft, Lady Radley, Lady Cockcroft, Sir Gordon Radley, Mrs. Knowles, Lord Citrine and Mr. J. O. Knowles

A.G.R. and Zeta

Turning to other types of nuclear reactor, Sir John mentioned the advanced gas-cooled reactor in which the fuel elements will be made of sintered uranium oxide and sheathed in beryllium. The advantage of this type of reactor is that uranium oxide has a melting point of 2400° C, which allows an increase in the operating temperature. Uranium oxide, however, has a low thermal conductivity, but this can be mitigated by using clusters of small-diameter rods. While the fuel costs of such reactors will be much the same as those of the 1960 versions of the Calder type, the capital costs will be reduced. 'We believe', said Sir John, 'that when this third generation of nuclear power stations comes into commission in the second half of the 1960's we shall have gone a long way towards meeting the prediction of Sir Christopher Hinton . . . that by 1970 the over-all cost of electricity for nuclear stations would be about 0·47 pence per unit.'

Sir John Cockcroft concluded his paper with a brief account of power from fusion processes. In Zeta, a stable discharge channel carrying 200 000 amp for several milliseconds had been obtained, and it was hoped to improve greatly on this performance as more and more energy was fed in.

The conference was terminated in a friendly way with a cocktail reception held at the Palais de l'Elégance—a superbly designed and smartly appointed salon in the grounds of the exhibition. It is to be hoped that this beautiful building is not among those scheduled for demolition when the fair ends. As might be expected, many well-known members of our Institution were present at the gathering; indeed, an absent-minded observer could have been excused for confusing it at times with The Institution's Conversazione.

SHORT REVIEWS OF PAPERS

On the following pages are some brief review articles based on, and written by the authors of, current Institution papers. The authors have been asked to make these articles, so far as possible, interesting and of appeal to electrical engineers who have no specialized knowledge of the subjects, and the content of the articles is not necessarily confined to the subject-matter of the original papers.

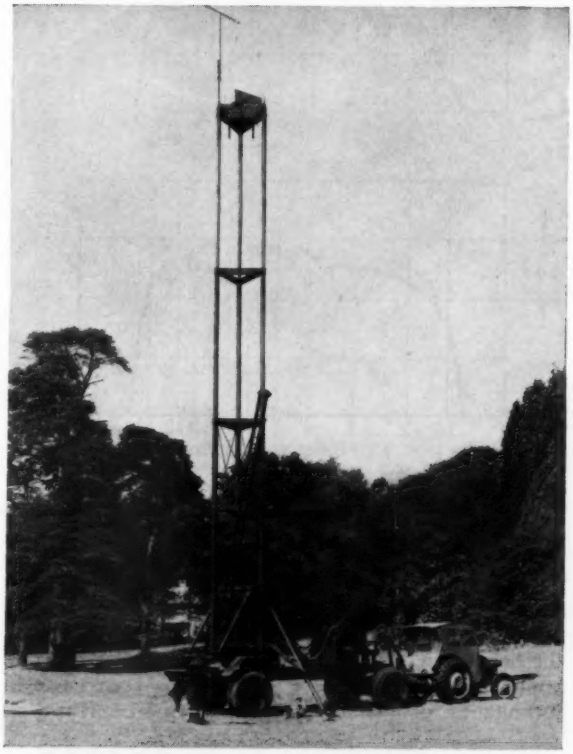
Monitoring Loudspeakers

A short review of a Radio and Telecommunication Section paper (No. 2604) entitled 'A Survey of Performance Criteria and Design Considerations for High-Quality Monitoring Loudspeakers', by D. E. L. Shorter, B.Sc.(Eng.), Associate Member. The paper was published individually in April 1958, and it will be republished in Part B of the Proceedings. The author is with the British Broadcasting Corporation.

BROADCASTING AND RECORDING ORGANIZATIONS USE high-quality monitoring loudspeakers to check the programme material for technical faults and to guide the studio staff in aesthetic matters such as the balance between a soloist and an accompanying orchestra. The performance of these loudspeakers is subject to very critical appraisal, since those who use them are in a position to compare the reproduced sound with the original. The design of monitoring loudspeakers therefore introduces all the problems of 'high-fidelity' in their most acute form.

Complete realism in reproduction by a single loudspeaker is not possible, even in theory. Moreover, apart from a few obvious generalizations, the properties of a loudspeaker which will give the nearest approach to the ideal cannot be prescribed from first principles. Attempts have, however, been made to discover the subjective significance of particular features taken individually, though some attributes of a loudspeaker, notably those connected with sound distribution, have only in recent years received much attention.

To facilitate analysis, most measurements of loudspeaker performance are made under free-field conditions, i.e. without the disturbing effects of wall reflections which appear in the normal working environment. At low frequencies such conditions can best be realized—weather permitting—in the open air. Fig. 1 shows, for example, a loudspeaker and measuring microphone mounted on a telescopic tower which can be extended as required by a hydraulic mechanism. It is difficult to predict, from the free-field frequency characteristics, the performance in a live room, where much of the sound reaches the observer after being radiated in different directions. Since the frequency response varies with direction, the over-all result needs to be represented by

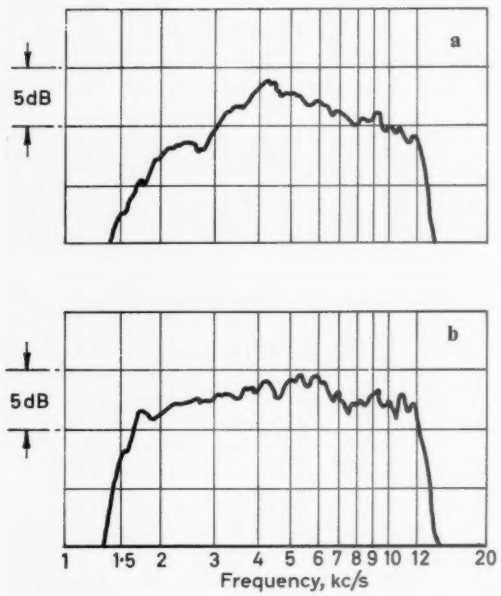


1 *Outdoor measurement of loudspeaker characteristics, using 55 ft tower to avoid ground reflection*

2 *Example of modern direct-radiator high-frequency unit*

some kind of composite frequency characteristic; attempts have been made—with varying success—to calculate this by adapting to acoustics the concept of 'mean spherical candle power' used by lighting engineers.

There is still no general agreement as to how smooth the frequency characteristics of a loudspeaker need be.



3 *Axial frequency response of a pair of high-frequency units*
a Mounted in free space
b Mounted in a large baffle

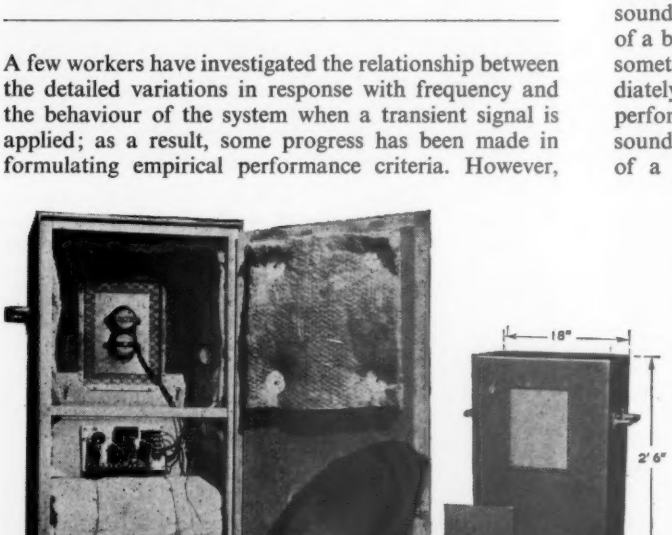
A few workers have investigated the relationship between the detailed variations in response with frequency and the behaviour of the system when a transient signal is applied; as a result, some progress has been made in formulating empirical performance criteria. However, there remain a number of subjective effects which cannot be completely accounted for by a study of the frequency response; it may therefore be necessary in future to pay more attention to the phase characteristics of loudspeakers, a matter which has hitherto been somewhat neglected because of the instrumental difficulties involved in the measurements.

The design of loudspeaker diaphragms has never fully yielded to mathematical treatment, and development is still a slow process of trial and error. Experimental study is hampered by the high tooling costs; several hundred pounds may have to be expended in order to discover the effect of a small change in shape. Much progress has, however, been made in the design of supplementary units for the high-frequency range. One of the more unusual types of present-day direct-radiator high-frequency units is illustrated in Fig. 2; it resembles in form the 'pressure unit' of a horn loudspeaker.

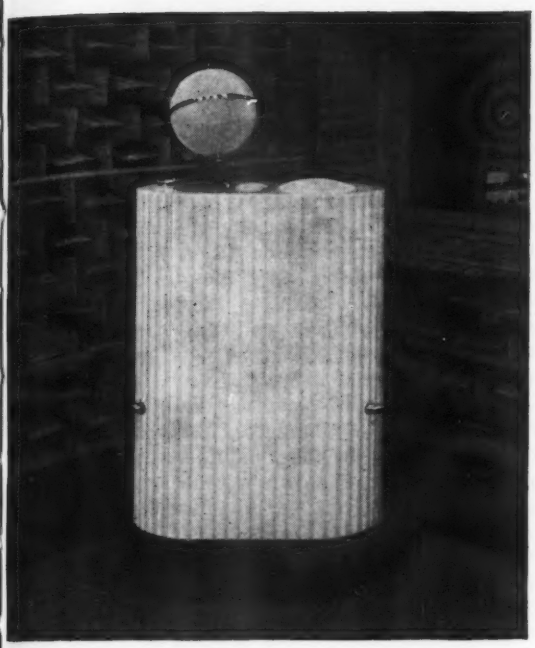
Considerable attention has been devoted to the problem of reducing the size of the cabinet in which a loudspeaker unit is mounted, without impairing the performance of the system at low frequencies; in spite of much ingenuity, however, no major change in principle has been introduced for more than two decades. In recent years, the effect of cabinets and baffles on the loudspeaker characteristics at higher frequencies has begun to be appreciated. Figs. 3*a* and *b* show, for example, the response of a pair of h.f. units of the type illustrated in Fig. 2, mounted, respectively, in free space and in a large baffle; the characteristics, which were measured at a distance of 4ft 6in on an axis midway between the axes of the individual units, include the effects of the crossover network and of other circuit components. Although no sound escapes from the rear of the system, the presence of a baffle can still improve the frequency response. It is sometimes necessary for h.f. units to be mounted immediately in front of the associated l.f. unit; a partially perforated baffle plate can then be used, thus allowing sounds of low frequency to pass. Fig. 4 shows two views of a portable loudspeaker developed by the British Broadcasting Corporation employing this arrangement.

Future developments in high-quality loudspeakers are likely to produce some unusual directional characteristics. An extreme example of this trend is shown in Fig. 5, which illustrates a loudspeaker used by the German broadcasting authorities. The h.f. radiator consists of twelve small cone units, mounted in spherical formation; the l.f. unit is of conventional design but is mounted with its axis vertical. The object of this elaborate arrangement is to make the radiation pattern omnidirectional at high frequencies as well as low. In a later version, the number of l.f. units is increased to three and the number of h.f. units to 32.

Full-range electrostatic loudspeakers employing large-area plastic diaphragms have lately been under intensive development and have



4 *Portable loudspeaker employing two high-frequency units mounted on a perforated baffle*



5 *Omnidirectional loudspeaker employing 12 high-frequency units*

important possibilities for the future. One of their most striking features is the absence of a cabinet; at low frequencies the unit acts as a doublet source, and the directional characteristic approximates to a cosine law instead of the usual omnidirectional distribution. Whatever the merits or shortcomings of these electrostatic loudspeakers as a class, it seems likely that their cost may eventually be less than that of a conventional multi-unit assembly of comparable quality. 621.395.623.7

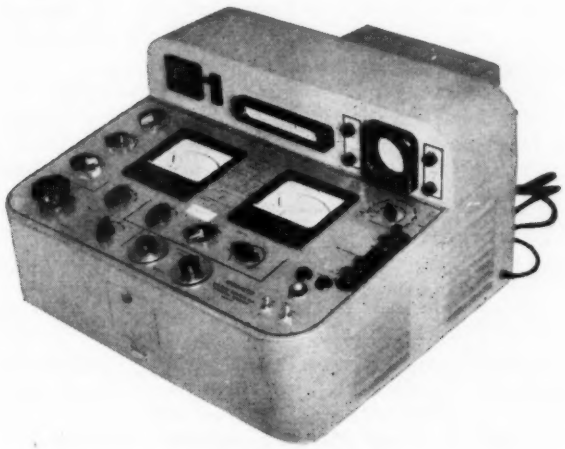
A Ferrometer from Finland

A short review of a Measurement and Control Section paper (No. 2482) entitled 'A Ferrometer for the Determination of the A.C. Magnetization Curve and the Iron Losses of Small Ferromagnetic Sheet Samples', by Prof. H. Blomberg, D.Sc., and P. J. Karttunen, M.Sc. The paper was published individually in January 1958 and is republished this month in Part A of the Proceedings. The authors are at the State Institute for Technical Research, Finland.

IN 1952, IN THE STATE INSTITUTE FOR TECHNICAL RESEARCH, Finland, a ferrometer was completed which enabled the a.c. magnetization curve and the iron losses of small ferromagnetic sheet samples to be measured (Fig. 1).

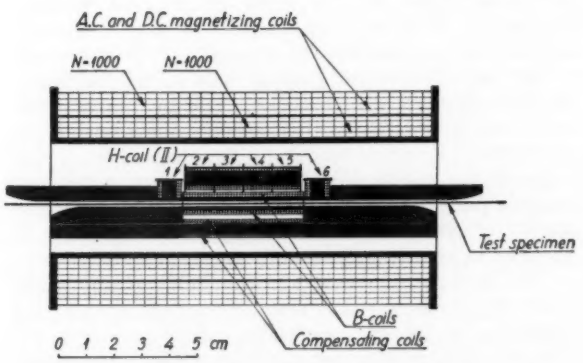
The measuring ranges* of the instrument are:

Frequency	50–250 c/s
Field strength	$0{\cdot}2–5 \times 10^4$ amp/m when $f = 50$ c/s
	$0{\cdot}04–10^4$ amp/m when $f = 250$ c/s
Magnetic flux Density	0·0004–10 Wb/m² when $f = 50$ c/s
	0·00008–2 Wb/m² when $f = 250$ c/s
Iron losses	$8 \times 10^{-8}–5 \times 10^3$ watts/kg when $f = 50–250$ c/s
Cross-section of the test specimen	4–40 mm²



1 *Appearance of the ferrometer*

Magnetization of the test specimen takes place with the aid of an open-ended coil supplied with sinusoidal voltage (Fig. 2), in the middle of which the test specimen



2 *Design of the magnetizing and pick-up coils*

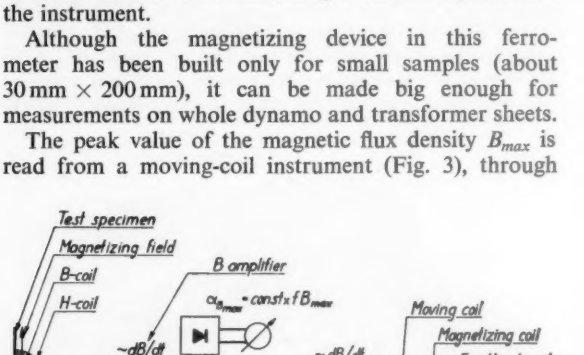
is placed. The magnetic flux density is then sinusoidal up to about 1·4 Wb/m² density. The specimen can also be magnetized in such a manner that a d.c. field is superposed on the a.c. field. This cannot be directly measured by means of the H_{max} measuring instrument, which operates

* Parts of the above-mentioned measuring ranges have no practical significance, e.g. 10 Wb/m² when $f = 50$ c/s, and 5×10^3 watts/kg

on alternating current only, but it can be set at the desired value with the aid of a calibrating device incorporated in the instrument.

Although the magnetizing device in this ferrometer has been built only for small samples (about 30 mm × 200 mm), it can be made big enough for measurements on whole dynamo and transformer sheets.

The peak value of the magnetic flux density B_{max} is read from a moving-coil instrument (Fig. 3), through



3 *Schematic showing principle of operation of the ferrometer*

which passes the rectified output current of the negative-feedback B amplifier; this output current is proportional to the e.m.f. induced in the B coil surrounding the specimen and in the compensating coil connected in series with the first-mentioned coil. The compensating coil compensates for the effect of the flux passing between the B coil and the specimen, in such a manner that the e.m.f. controlling the B amplifier is proportional to the derivative of the magnetic flux in the specimen. The gain of the B amplifier is regulated by means of the cross-section switches, so that the output current of the B amplifier is proportional to the derivative of the magnetic flux density whenever the cross-section switches are in a position indexed that corresponds to the cross-section of the specimen. The B_{max} measuring range is changed by changing the B coil.

The instrument measuring the field-strength peak value H_{max} operates in a manner corresponding to the operation of the B_{max} measuring instrument (Fig. 3). The sole difference is that the H amplifier is controlled by a Rogowski-type H coil, in which an e.m.f. proportional to the derivative of the field strength in the specimen is induced. The deflection of the moving-coil instrument is then proportional to H_{max}. The measuring range is altered partially by changing the H coil and partially by adjusting the gain of the H amplifier.

The iron losses are read from a wattmeter with a light-beam pointer. Through the moving coil of the wattmeter passes the output current of the B amplifier, which is proportional to dB/dt (Fig. 3). The field coil is controlled by the negative-feedback iron-loss amplifier in such a manner that the magnetic flux Φ_W in the air-gap of the wattmeter is proportional to the integral of the output voltage of the H amplifier which controls the iron-loss amplifier. Φ_W is then proportional to the field strength in the specimen, and the deflection of the wattmeter is proportional to the iron losses.

The measuring accuracy of the ferrometer is dependent on the magnetic flux density. At high densities the dB/dt and dH/dt curves suffer distortion; they become excessively peaked and contain strong harmonics. As a consequence, the output currents of the H and B amplifiers no longer follow accurately the peaks of the e.m.f.'s controlling these amplifiers and their harmonics. At high densities also the phase shift between the dB/dt and H quantities controlling the wattmeter is so close to 90° that the angular error caused by the B, H and iron-loss amplifiers has a considerable effect upon the deflection of the wattmeter. The distortion of the density curve has also the result that the losses indicated by the wattmeter no longer correspond to a sinusoidally alternating magnetic-flux density.

It has been calculated that the accuracy of measurement of the ferrometer is about ±2% for field strength, ±1·5% for flux density, and ±3% for iron losses, when the amplifier outputs are sufficient to provide also for the signal peaks and when the effect of the error angle is negligible. With normal dynamo and transformer sheets the measuring accuracy of the magnetizing curve is as good as this up to a density of about $B_{max} = 1{\cdot}7$–$1{\cdot}8$ Wb/m². Moreover, the curve obtained is independent within the reading accuracy of the instruments of the measuring frequency in the range 50–250 c/s.

It has been established by means of control measurements that the measuring accuracy of iron losses is at least approximately of calculated magnitude as long as the magnetic flux in the specimen is not considerably distorted.

621.317.43

New Iron-Loss Testing Methods

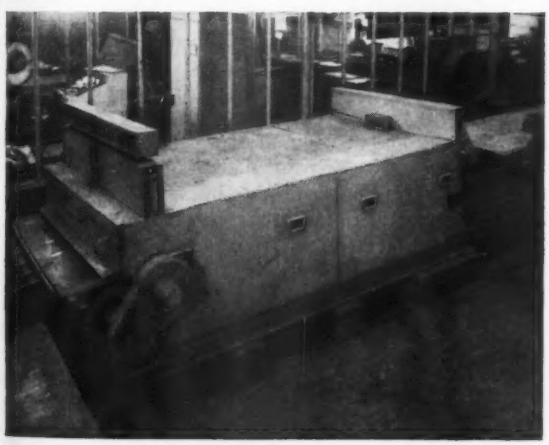
A short review of two Measurement and Control Section papers (Nos. 2553 and 2554) entitled 'Direct-Reading Iron-Loss Testing Equipment for Single Sheets, Single Strips and Test Squares', by J. McFarlane, B.Sc., Associate Member, P. Milne, Associate Member, and J. K. Darby, B.Sc.(Eng.), Associate Member; and 'The Control of Flux Waveforms in Iron Testing by the Application of Feedback Amplifier Techniques', by J. McFarlane, B.Sc., Associate Member, and M. J. Harris, B.Sc. The papers were published individually in February 1956 and are republished this month in Part A of the Proceedings. Mr. McFarlane, Mr. Darby and Mr. Harris are at the Guest, Keen and Nettlefolds Group Research Laboratory; Mr. Milne, who was formerly at that laboratory, is now with Electric and Musical Industries Ltd.

DURING THE LIFETIME OF A POWER TRANSFORMER, THE cost of energy dissipated in iron losses in the core is of

the same order as the capital cost of the transformer itself. This fact has placed a premium on low-loss material and has encouraged the marketing of successive grades of electrical steel differing in loss by relatively small amounts—often about 7%. The burden of grading large quantities of material, which falls on the steel manufacturer, calls for rapid and accurate methods.

The testing is based on the measurement of specific iron loss at a known frequency (usually 50 c/s) and flux density (usually 1·3 Wb/m^2 for non-oriented sheet and 1·5 Wb/m^2 for grain-oriented strip). The classical methods of Epstein, and of Lloyd and Fisher, in which sample strips are cut and assembled in a test square, are still employed for the lower-silicon dynamo grades and for oriented material, though with some modification. Developments during the last decade have speeded up the process by eliminating correction factors and by including computing circuits in the test equipment, so that direct readings of flux density and specific loss are obtained.

With hot-rolled transformer sheet, the spread of losses between individual sheets in a batch often exceeds the 7% difference between grades. A sampling technique cannot ensure correct grading of every sheet, and the whole batch may sometimes be incorrectly graded if the samples are unrepresentative. These circumstances justify individual testing of every sheet and have led to the development by the authors of a single-sheet tester, shown in Fig. 1, capable of testing up to 400 sheets per hour.



1 *Single-sheet tester*

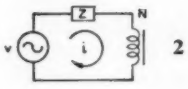
The test bed and weighing platform are seen in the foreground. Behind them is the operator's cabin, which contains the instrument console and amplifier unit

The electrical-steel manufacturer often finds it useful to be able to measure the magnetic properties of small strips, for example to compare annealing processes or to find the distribution of losses over a whole sheet. The authors have also developed a single-strip tester which is essentially a small-scale version of the sheet tester, though the difference in size requires appreciable changes in technique.

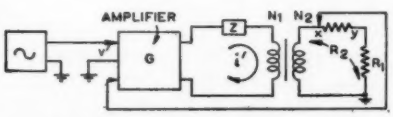
The three types of equipment outlined above have a good deal in common. The problem resolves itself into two parts—magnetizing the test specimen and measuring the specific iron loss—which are now considered separately.

Magnetizing the Test Specimen

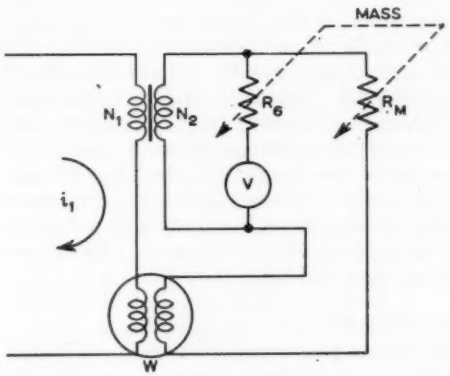
Iron losses are dependent on the magnitude, frequency and waveform of the flux density. To obtain reproducible results, a sine waveform of flux density is obviously desirable. When an iron core is magnetized from a sine-wave generator, as in Fig. 2, the non-linear *B*|*H* characteristics of the iron cause harmonic-frequency magnetizing currents to flow, resulting in harmonic voltage generation across the series impedance *Z*, which represents the impedance of the generator and the resistance and leakage reactance of the coil. Corresponding harmonic voltages are induced in the coil N, so the flux waveform cannot be sinusoidal. At high flux densities the *B*|*H* characteristic becomes increasingly non-linear, and it is difficult even in test squares to achieve satisfactory waveforms, which results in a need for corrections based on form-factor measurement. The



2 *Magnetizing circuit for iron sample*



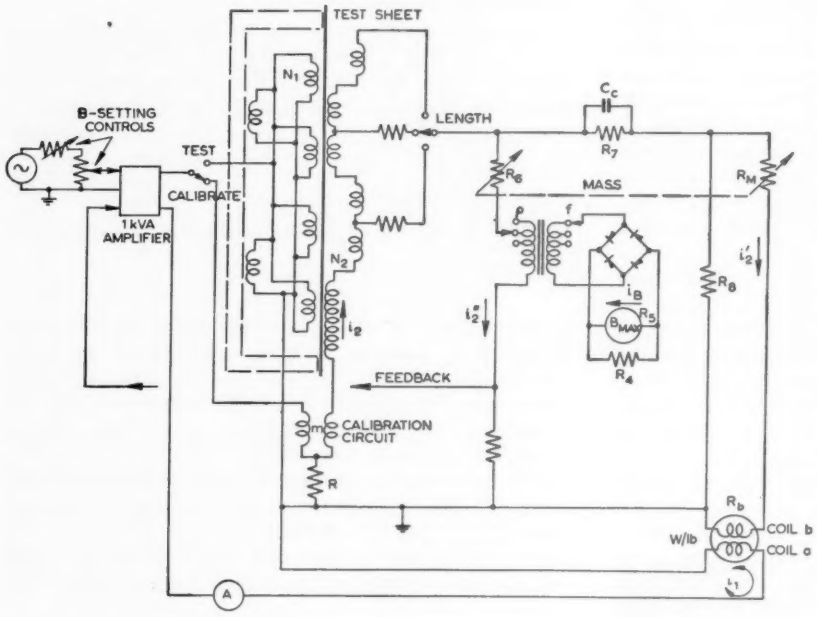
3 *Feedback amplifier control of flux waveform*



4 *Basic iron-loss measuring circuit*

distortion is intensified in single-sheet testers because the test coil encloses only a single thickness of core material, although its leakage reactance is not reduced by a corresponding amount.

Waveform distortion has been overcome by the method shown in Fig. 3. Here the magnetizing current i' is provided by an amplifier which receives a driving voltage v' from an oscillator, and an opposing feedback voltage from a search coil N_2 surrounding the iron sample. If the loop gain is large, the feedback voltage will follow the driving voltage in magnitude and waveform. Thus errors due to waveform distortion are overcome, and the stability of frequency and flux density is of the same order as the frequency and amplitude stability of the oscillator. Successive test samples will generally differ in thickness, and this will alter the voltage required across N_2 for a given flux density. Allowance is made by moving the feedback point from x to y and varying the ratio R_2/R_1 in proportion to the mass (i.e. cross-section) of the sample. On the single-sheet tester this function is performed when the sheet is weighed before entering the test bed. Thus automatic setting of flux density is achieved. This equipment employs an amplifier with a rating of 1 kVA.



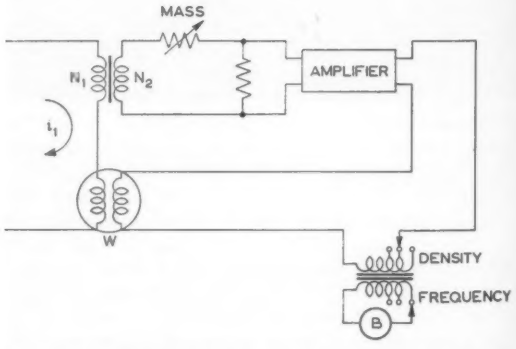
5 *Circuit of single-sheet tester*

Iron-Loss Measurements

In the classical iron-loss testing circuit (Fig. 4) the flux density is inferred from the reading of the average voltmeter V, while the wattmeter W records the sum of the iron loss and the copper losses incurred by loading the secondary winding N_2. In the single-sheet tester, the mass of iron under test (about 10 lb) is sufficiently large to make the copper losses negligible in comparison, and the addition of variable resistors R_6 and R_M, which are mounted on the weighing machine, enables the total circuit resistance to be made proportional to the mass of the sheet, so that the voltmeter records flux density and the wattmeter records specific loss. The magnetizing coil N_1 is wound in a number of parallel sections, some of which enclose a laminated U-shaped yoke which provides the return flux path and helps to achieve uniform flux density in the sheet. Unfortunately, the yoke loss is measured in addition to the sheet loss. For this reason the authors have used a very heavy yoke, which enables the yoke loss to be reduced to about 1 % of the sheet loss. A permanent correction is made in calibration.

In a more detailed circuit of the authors' sheet tester (Fig. 5), it is seen that other adjustments are provided to allow for a range of values of the length and density of the sheet, and of the test frequency. For calibration purposes a standard resistor R and a standard mutual inductor m can be switched into the circuit instead of the magnetizing coils. Various wattmeter ranges are provided by series/parallel switching (not shown in Fig. 5) of wattmeter coils.

Fig. 5 serves to illustrate direct-reading iron-testing methods, but this circuit is not directly applicable to test squares and single-strip testers, because instrument losses are no longer negligible compared with the iron loss. The alternative circuit of Fig. 6 is then used, in which an amplifier is interposed



6 *Application of amplifier in iron-loss measuring circuit*

to reduce the loading on N_2. At the low power factor (say 0·2) associated with iron testing, the wattmeter currents differ from phase quadrature by about 12°, and an amplifier phase error of 0·012° will cause a wattmeter error of 0·1%, which is the target figure for the maximum permitted error. The attainment of the low phase error requires that the amplifier should have a feedback factor of between 60 and 70dB. This presents many problems and requires double feedback-loop methods to ensure stability.

Conclusions

The application of the methods outlined above enables the electrical-steel manufacturer to carry out his tests both rapidly and accurately. In particular, the introduction of individual grading of sheets of transformer steel achieves, for the benefit of the transformer manufacturer, a higher degree of uniformity than has previously been possible, while the strip tester provides the sheet manufacturer with yet another of the tools of research.

621.317.44 : 621.318.13

Magnetic Amplifiers

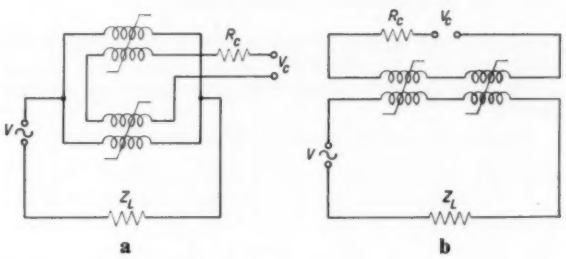
A short review of a Graduate and Student Section paper entitled 'The Performance and Application of Magnetic Amplifiers', by J. W. S. Payne, B.Sc.(Eng.), Graduate. The paper was read before the Rugby Graduate and Student Section on the 8th January 1957, and it was awarded a Graduate and Student Premium by the Council. The author is with the British Thomson-Houston Co.

THE FUNDAMENTAL MAGNETIC AMPLIFIER CONSISTS OF A saturable reactor with a single core wound with a load and a control winding (Fig. 1). The load winding is in series with the load Z_L and is supplied from an a.c. source V. The output voltage is that developed across Z_L. The control winding is fed through a high impedance to minimize the effect of induced alternating current flowing in the d.c. control circuit. The operation of the circuit depends upon the fact that the instantaneous impedance of the saturable reactor, and hence the magnitude of the load current, is a function of the direct control current. The transfer characteristic relating control and load magnetomotive force is non-linear, and the simple magnetic amplifier suffers from the following severe disadvantages:

1. Voltages of fundamental supply frequency are induced in the control winding
2. To eliminate the effects of the induced voltage, either an inductor or a series resistor must be inserted into the control circuit, the former solution leading to poor transient response and the latter to low power gain for the amplifier.

This type of control is therefore used only in systems such as theatre-dimming circuits where good transient response is unnecessary and can be subordinated to cheapness.

The disadvantage of alternating voltage being induced in the control windings can be overcome by using two saturable reactors. The control windings are connected in anti-phase so as to cancel out the fundamental of the alternating induced voltage, and the saturable reactors are connected with their output windings either in series or parallel (Fig. 2). These two alternative connections

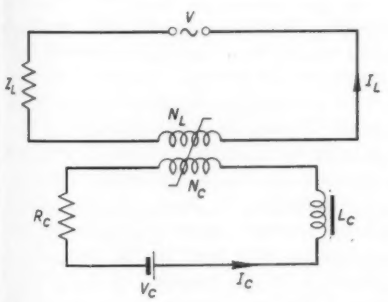


2 *Saturable reactors*
a Parallel connected b Series connected

give rise to two distinct operating conditions depending on whether even harmonic currents are suppressed or allowed to flow in the reactor windings.

With series-connected load windings and a very high control-circuit impedance, the even harmonics are suppressed, and the waveform is nearly rectangular in shape (Fig. 3*a*). With parallel-connected load windings, or with series-connected load windings with *low* control-circuit impedance, the even harmonics are not suppressed, and the load-current waveform is of a steep pulse shape (Fig. 3*b*). It is important for the circuit designer to know within limits the waveshape of the load current, since the form factor will be affected, and load components, such as machines, may have to be derated.

The transfer characteristic for saturable reactors with free second-harmonic flow is a linear function up to saturation, but where the second harmonic is suppressed,

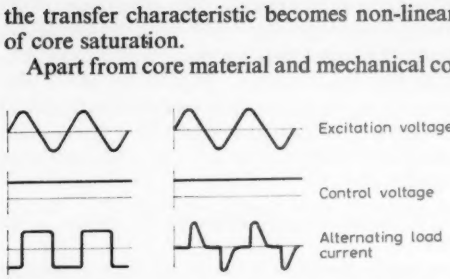


1 *Fundamental magnetic-amplifier circuit*

V = alternating supply voltage
I_L = load-circuit current
N_L = load-circuit winding
Z_L = load-circuit impedance
V_C = direct control voltage
I_C = control-circuit current
N_C = control-circuit winding
R_C = control-circuit resistance
L_C = control-circuit inductance

the transfer characteristic becomes non-linear just short of core saturation.

Apart from core material and mechanical construction,



3 *Output-current waveforms*
a Second harmonic suppressed **b** Second harmonic free

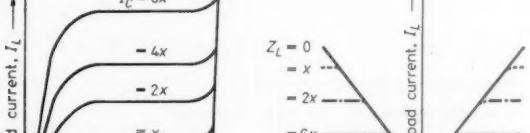
three fundamental conditions affect the operation of a given amplifier:

1. The amplitude of the alternating excitation supply voltage
2. The load impedance
3. The control-circuit impedance.

Thus for the optimum use of a given amplifier it is necessary to know the relations connecting:

1. Load current I_L as a function of excitation voltage V with control current I_C as a parameter
2. The transfer characteristic with load resistance R_L as a parameter.

Typical curves are shown in Figs. 4*a* and 4*b*.



4 *Typical characteristics*
a Variation of load current with excitation voltage for various values of control current
b Variation of load current with control current for various values of load impedance Z_L

In most applications, magnetic amplifiers form part of a closed-loop servo control system, and the over-all time-constant of the amplifier must be kept small if the system is to have good accuracy with stability.

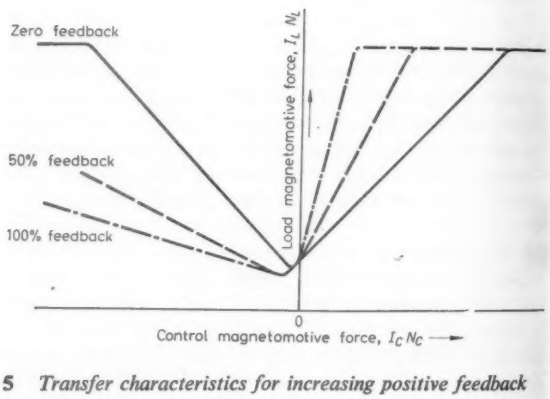
The time-constant of a fully excited amplifier is a function of control and load winding inductances and resistances, leakage reactance, etc. and may be expressed in general as (effective inductance)/(effective resistance), the actual value depending on the connection used; but in each case the time-constant is inversely proportional to the supply frequency.

In addition to inductive time lags, the magnetic amplifier has a time-constant known as *dead time* or *transportation lag*, when it is under-excited.

To minimize the over-all time-constant, the amplifier should be designed to run at the highest possible frequency consistent with a tolerable eddy-current loss and in the fully- or over-excited condition.

From a mathematical analysis it can be shown that for a particular working condition the ratio of power gain and time-constant equals a constant termed the *figure of merit*. Thus, any increase in power gain is obtained at the expense of a longer time-constant. However, for a given amplifier the use of positive feedback can improve the gain without affecting the time-constant.

Feedback can be applied to both parallel- and series-connected saturable reactors by rectifying the output current and feeding it back in the same sense as the control current. The feedback can be varied from zero to 100%, with effect on the transfer characteristic as shown in Fig. 5. The effect of feedback on the time-



5 *Transfer characteristics for increasing positive feedback*

constant is extremely complex, because the effect of rectifier leakage current, forward resistance and capacity cannot easily be predicted. In general, the figure of merit for an amplifier with positive feedback will be equal to that for an amplifier without feedback multiplied by a feedback factor greater than unity, and the power gain will be increased without increasing the time-constant.

It is always an advantage to keep the number of windings on saturable reactors down to a minimum to avoid excess flux leakage and heating. In the case of 100% positive feedback, it is possible, by inserting a rectifier in series with the load windings, to utilize the load windings as the feedback windings and make the amplifier self-excited.

Rectifier characteristics are extremely important in this type of amplifier since any reverse current operates to cancel the positive feedback. With good rectifiers, gains

of the order of 10^6 can be obtained, with a figure of merit of 5000. Since each period of output must be preceded by a period which controls, by means of a flux-setting action, the amount of output to be delivered, the amplifier has an inherent time delay of a maximum of one cycle in addition to the normal time-constant.

Where very fast response is not required, auto-excited amplifiers have given extremely good service with stability and ease of control.

For applications where very fast response coupled with high gain is required, the flux-reset class of amplifier can be used. Negligible power is used for control, the effective control power being obtained from the amplifier itself. The main advantage of this class of amplifier is the inherent half-cycle response, which is virtually independent of the power gain. This advantage, however, is offset by the bad form factor of the output waveform, which is due to the inclusion of a large proportion of higher harmonics and to the fact that the control circuits must possess a lower impedance than would be necessary with other classes of magnetic amplifier. However, a transistor pre-amplifier with a flux-reset magnetic amplifier supplying the power is an ideal combination for accurate high-speed servo systems, and it offers a considerable increase in efficiency over the conventional thermionic valve.

For many applications, such as motor control, the magnetic amplifier is required to be phase-sensitive and to give a two-directional output. This is not easy to provide in an efficient manner because the magnetic amplifier inherently gives a unidirectional output, but where the load can be split into two separate equal loads (e.g. a machine field) two magnetic amplifiers can be connected to form a conventional push-pull circuit. Where the load cannot be split there are many circuits available, but the efficiency is only of the order of 25–45%, and it is uneconomic at the present time to use phase-sensitive magnetic amplifiers for large power outputs.

Magnetic amplifiers are being used extensively in industry when the control must be robust, easy to maintain and of high accuracy. In the field of aeronautics, where weight and size are often at a premium, the magnetic amplifier has in many cases been found to be superior to the thermionic valve in both dynamic performance and resistance to shock. 621.375.3

SYNOPSES OF PAPERS

The following are synopses of papers published in the *Proceedings* which have not been read at an Institution meeting and which have not been described under 'Short Reviews of Papers'. They are included here primarily for reference. The papers have not been published individually, as have those for reading at meetings, but reprints of them will be available shortly (see p. 460).

Capacitors for Discharge-Lighting Control Circuits

A synopsis of a Utilization Section paper (No. 2664) with the above title, by J. P. Pitts, B.Sc.(Eng.), Associate Member. The paper is published this month in Part A of the Proceedings. Mr. Pitts is with the General Electric Co.

A SHORT SECTION ON MANUFACTURE AND MATERIALS outlines typical features in the construction of a capacitor for discharge lighting and refers briefly to common practice in the choice of impregnating material and vacuum processing conditions.

Under the general heading of dielectric life and breakdown the probable effects of conducting paths in tissue are mentioned. The importance of discharge-inception stress is emphasized, reference being made to discharge-inception measurements on capacitors impregnated with petroleum jelly and with pentachlorodiphenyl, and to the interim results of long-term accelerated tests on pentachlorodiphenyl-impregnated capacitors. A suggestion that electrochemical deterioration is not a major factor contributing to failure of paper capacitors under a.c. stress is discussed. There is a note on chemical decomposition of impregnants during breakdown, followed by discussion of the use of fusing to reduce or eliminate such chemical effects. A final section discusses power factor as a criterion of capacitor quality.

621.319.4 : 621.327

Induction-Motor Speed-Changing by Pole-Amplitude Modulation

A synopsis of a Utilization Section paper (No. 2597) with the above title, by Prof. G. H. Rawcliffe, M.A., D.Sc., Member, R. F. Burbidge, B.Sc., Graduate, and W. Fong, Graduate. The paper is published this month in Part A of the Proceedings. Prof. Rawcliffe and Mr. Fong are in the University of Bristol. Mr. Burbidge is now with the English Electric Co.

AN ORIGINAL METHOD OF CHANGING THE SPEED OF squirrel-cage induction motors has recently been developed which enables efficient and economic operation to be obtained at either of two chosen speeds, using a single winding of standard type.

The method has considerable generality, but is particularly applicable to speed ratios not very different from unity. The initial tests have therefore been performed on a motor for two speeds in the ratio 5: 4, but a variety of ratios can be obtained by using the same principle. The control gear needed is extremely simple.

621.313.333.2 : 621.316.765

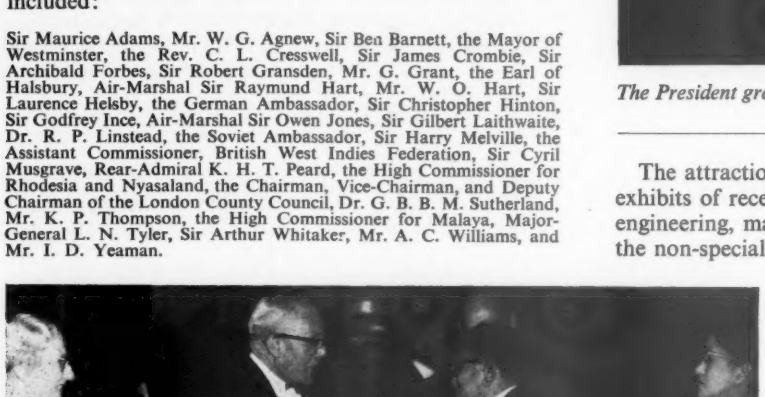
CONVERSAZIONE 1958

EVIDENCE accumulates, showing that the Conversazione is coming more and more to be regarded by The Institution's guests as one occasion, among the many to which they are invited, that it would be foolish to miss. Despite the rain, more than 2000 members and guests on the 25th June enjoyed, in the ways of their choice, a most successful evening in the setting of London's South Bank Royal Festival Hall. All six levels of the hall, including the concert auditorium, were used for activities of one kind or another, and the surroundings lent spaciousness and added gaiety to the scene.

For about an hour, from 7.30, the President and Mrs. Goldup and the President-Elect and Mrs. Goodall received members and guests in the upper foyer. Guests included:

Sir Maurice Adams, Mr. W. G. Agnew, Sir Ben Barnett, the Mayor of Westminster, the Rev. C. L. Cresswell, Sir James Crombie, Sir Archibald Forbes, Sir Robert Gransden, Mr. G. Grant, the Earl of Halsbury, Air-Marshal Sir Raymund Hart, Mr. W. O. Hart, Sir Laurence Helsby, the German Ambassador, Sir Christopher Hinton, Sir Godfrey Ince, Air-Marshal Sir Owen Jones, Sir Gilbert Laithwaite, Dr. R. P. Linstead, the Soviet Ambassador, Sir Harry Melville, the Assistant Commissioner, British West Indies Federation, Sir Cyril Musgrave, Rear-Admiral K. H. T. Peard, the High Commissioner for Rhodesia and Nyasaland, the Chairman, Vice-Chairman, and Deputy Chairman of the London County Council, Dr. G. B. B. M. Sutherland, Mr. K. P. Thompson, the High Commissioner for Malaya, Major-General L. N. Tyler, Sir Arthur Whitaker, Mr. A. C. Williams, and Mr. I. D. Yeaman.

The President greets the Soviet Ambassador



The High Commissioner for Malaya, His Excellency Tunku Ya 'acob, and his wife are received by Mr. and Mrs. Goldup

Mr. and Mrs. S. E. Goodall greeting Mr. and Mrs. E. Smith

The attractions thereafter were varied. More than 70 exhibits of recent developments in electrical science and engineering, many of them designed to be attractive to the non-specialist, were arranged in the upper foyer, the recital room and its ante-hall, the riverside promenade, and the third-level promenade.

Two concerts, each of about 40 minutes' duration, were heard in the auditorium by audiences large enough to please the box-office manager even on an ordinary concert night. The music of the band of the Irish Guards and the singing of Jacqueline Delman provided a pleasant contrast and something for nearly every taste. Dancing from 8.30, in the foyer, naturally became more popular as the evening wore on, but the floor was not too crowded. The bars and buffets were well patronized and well organized.

Viewing the exhibits, a continuous stream of people satisfied their curiosity and thirst for knowledge at the many ingenious displays. It is impossible to mention all the demonstrations, but some that caught the eye were 'electronics in the insect world'—with 'beetles', motorized and photo-transistorized, being attracted or repelled across a table by movable light sources; a

Indoor fireworks, too?

This display embodied a unit developed to provide internal supplies of electric and hydraulic power to a missile while in flight

Sir Godfrey Ince is received by the President

working model of the 'mirror sight' system of landing aircraft onto the deck of an aircraft carrier at sea; an early liquid-propellent rocket engine developed for the projection of experimental guided missiles; a model of Hinkley Point nuclear power station; the visible path of an ultrasonic beam in quartz; Daedalus, a slow-speed computer designed to play the game of 'completing the squares'; a large working model of a machine used for the continuous drying, vacuum treatment and impregnation of the paper which forms part of the gas-filled cable dielectric; a miniature solar motor using silicon photocells; and an apparatus for studying the tracking characteristics of a human operator—a method having possibilities of wider application for assessing the dynamic characteristics of industrial processes.

Though mostly pitched on a frankly technical plane, with no concessions to the mood of the occasion, the exhibition as a whole certainly did not lack for custom. The ladies, particularly, read the notices, peered into the eyepieces, gazed at the models, clapped their hands at the 'coin that hears', with all the absorption and interest of schoolboys at a hobbies exhibition.

One of the highlights of the evening was an exposition of colour television on closed circuit, which went on for about two hours. One of the B.B.C.'s experimental colour cameras from their studio at Alexandra Palace had been installed in the upper foyer, just above the ballroom, with Miss Sylvia Peters in attendance to coax, with her winning smile, expressions of opinion, talk about work, talk about play, talk about hobbies—in fact any kind of talk—from the braver souls who volunteered to sit on the interviewee's chair in the bright glare of the lights. At the five monitor receivers placed at various points in the hall, knots of viewers were able to appreciate the surprisingly natural colours and excellent definition of the fully encoded N.T.S.C. signal adapted for 405 lines.

This was, altogether, an evening to be remembered.

Mr. and Mrs. T. E. Goldup greet Air-Marshal Sir Raymund Hart and Lady Hart

The atoms go in here

Feminine interest in a model of a reactor unit for Berkeley nuclear power station

OBITUARY

BERNARD GILBERT DRUMMOND

Bernard Gilbert Drummond, who died on the 22nd October 1957, was born in Moffat, Dumfries, on the 10th December 1881. He was educated at Warriston College, Moffat, and at the School of Commerce, Berlin. He completed two apprenticeships: one with the Dumfries Iron Works and the other with Crompton and Co., Chelmsford, studying part-time in Chelmsford and at the Northampton Polytechnic Institute, London.

In 1902 he went to sea as an electrician with the Peninsular and Oriental Steam Navigation Co. and on returning to London became Engineer-in-Charge of Smithfield Market's electricity supply. In 1904 he was appointed Resident Engineer with the Electric Supply Corporation, London, supervising the erection of station, plant and mains at St. Andrews. In 1907 he joined the Hendon Electric Supply Co. as Resident Engineer and Manager, remaining in that position for 16 years. He then became General Manager of the East Anglian Electric Supply Co., the Bedfordshire, Cambridgeshire and Huntingdonshire Electricity Co. and the Newmarket Electric Light Co., retiring in 1946 after 23 years' service with the East Anglian Group.

He was a reliable, conscientious man, his chief interests being his children and his work. He was a widower and is survived by five sons.

Mr. Drummond joined The Institution as a Student in 1902 and was elected an Associate Member in 1908 and a Member in 1922.

B. D.

KENNETH NEWTON ECKHARD

Kenneth Newton Eckhard, who died on the 8th May 1958, was born on the 3rd November 1889. He was educated at Latymer Upper School, Hammersmith, and Ramsgate College. In 1905 he commenced an apprenticeship with Spagnoletti Ltd., continuing it in 1909 with the London United Tramway Co. In 1910 he joined the staff of the London Electric Railway Co. and in 1912 set out for the Argentine, after reading in a technical journal that the Central Argentine Railway was about to electrify its suburban lines.

On arrival in Buenos Aires in May 1912 he found that the electrification project was not yet under way. Undaunted, he worked for a year with the Tucuman Hydroelectric Co. and then joined the staff of the Central Argentine Railway as a draughtsman in the electrical section of the Mechanical Department. He was concerned with the laying of cables and other works connected with the traction substations, and in 1915 he became electrical assistant to the Works Manager at Victoria, the headquarters of the electrical section. In this capacity he was closely associated with the equipping of the electric rolling-stock and was in charge of the running shed.

In 1920 he was appointed Resident Engineer and made responsible, under the Chief Mechanical Engineer, for the running of the suburban electrified system which then comprised the line from the terminal of Retiro to Tigre C. Owing to his hard work and efforts, the electrical section became an autonomous entity in the railway organization, and in 1925 he was appointed Electrification Superintendent. Under his able direction, plans to electrify the other two suburban lines, Retiro to Tigre R and Retiro to km 24 on the main line to Rosario, were carried to fruition; and by the end of 1931 electric trains had replaced steam traction on these two lines, the power house being extended from 12 MW to 30 MW. He was never one to rest on his laurels and continued always to look for new fields to conquer, expanding and improving the electric suburban services; and in 1937 the organization, under his charge, took over the running of Diesel-engined railcar services on the outer suburban lines, eventually extending these to semi-long-distance services.

His efforts were eventually rewarded and recognized by the conversion of his organization into an independent department in 1946, when he was named Chief Electrical Engineer and took under his charge all the electrical installations on the railway. After the sale of the railways to the Argentine Government in 1947 he found conditions so irksome to one of his go-ahead nature that he resigned and retired on pension in October 1949.

He then undertook for the Argentine Ministry of Transport a study of the requirements for the efficient maintenance of Diesel-electric locomotives. At the end of April 1951 he returned to England and accepted the post of General Manager with the newly formed Brush Bagnall Traction Co., which he held until 1955, when ill health forced him to retire from professional activities.

Many would say he was a hard taskmaster, but, hard as he worked his staff in the never-ending search for greater efficiency, he never spared himself. At times impatient over small details, he was nevertheless tolerant, and under an apparently hard exterior there was a warm-hearted, deep-seated interest in the welfare of his staff.

'K.N.E.' was at heart a simple home-loving man, who managed to keep his private life apart and unaffected by his daily labours. His main interest, apart from his home life, was his work, but he found time to expend his unflagging energies in gardening, a hobby which seemed to act as an antidote to the nervous strain of his working day. His passing, sadly mourned by those who worked under him and were inspired by his energy and foresight, marks the end of an epoch which it is feared will never return.

Mr. Eckhard joined The Institution as a Member in 1927 and served on the Argentine Local Centre Committee from 1932 to 1946. He was Chairman of the Committee in 1930 and 1945.

B. G. B.

FRANK JOHNSTON

Frank Johnston, who died in March 1958, was born in London on the 7th June 1875. He was educated at Whitgift School and at Finsbury Technical College, London, under Professor Silvanus P. Thompson, where he took the Diploma in Electrical Engineering. He was apprenticed to Latimer Clarke, Muirhead and Co., Westminster, and in 1897 joined W. H. Allen of Bedford, being sent to Belfast in 1899 to be manager of their branch there. He joined Harland and Wolff in 1906 and retired as Chief of the Electrical Department in November 1948.

Johnston had a family of two boys and five girls. Both his sons predeceased him, his eldest boy dying at the age of 21 just after completing his apprenticeship as an engineer, and his second son who was an Army Officer, being killed in France shortly after the Normandy landings.

Johnston's chief hobby was rifle shooting; he was a crack shot and competed at Bisley until a very few years ago. He was champion shot of Ireland for many years, and soon after the end of the Second World War, during which he continued to hold his championship, he shot again for Ireland at the age of 75 and won.

His retirement was spent in a delightful spot in the Mountains of Mourne, on the side of Slieve Donard, the highest mountain, overlooking the Irish Sea.

Mr. Johnston joined The Institution as a Student in 1895 and was elected an Associate in 1897, an Associate Member in 1902, and a Member in 1911. He was Chairman of the Northern Ireland Sub-Centre in 1938, serving on the Committee from 1936 to 1944. He was awarded a Student Premium in 1897 and was an early member of the Committee on Regulations for the Electrical Equipment of Ships. His progress review entitled 'Electricity Applied to Ships' was published in the *Journal* in 1933.

H. C. M.

PERCIVAL ANDRÉ LUNDBERG

Percival André Lundberg, who was born on the 19th August 1868, died recently only a few months before his 90th birthday. He was the last surviving member of the Lundberg family, and all his life

he had been closely associated with the firm of A. P. Lundberg, makers of electrical accessories. The firm was founded in 1882 by his Swedish father, who was the first to produce the tumbler switch, which had many advantages over the rotary switch. Lundberg was educated at Haberdashers' Aske's School from 1882 to 1885. He became assistant manager, and later a partner, in his father's firm, and he and his brother were brought up in an atmosphere of hard work. Part of the day was spent in their father's small workshop and the rest in studying at the City and Guilds College and Regent Street Polytechnic for their diplomas.

Lundberg dedicated himself to the commercial organization of the firm. His life was divided between the management of the factory and devotion to his beloved wife, for the sake of whose health he lived at Hastings and travelled daily to his work in Holloway, London.

In spite of everyday worries, he maintained his good humour, and his repartee was always sensible and witty.

His greatest pleasure was to live close to nature, and he liked to be alone in his garden tending the flowers. He was always strongly attracted to the sea. Like Churchill and his cigar, one rarely met Lundberg without his pipe and his particularly fragrant blend of tobacco.

Since losing his wife 25 years ago, he had lived alone, away from the world and its troubles, in a modest little cottage at Hastings.

His death means the termination of a family whose name was known throughout the world in connection with high-quality electrical accessories.

Mr. Lundberg joined The Institution as an Associate Member in 1911 and was elected a Member in 1912. A. A.

CAMILLE NICOLAS MATHIEU

Camille Nicolas Mathieu, DOCTEUR EN DROIT, ING.E.S.E., who was born on the 16th October 1884, died on the 14th October 1957. He attended the University of Nancy from 1902 to 1905, and subsequently spent a year at the École Supérieure d'Électricité, where he obtained his diploma. He began his career as an electrical engineer with Siemens Schuckert, Berlin, and Siemens Bros., London, and from 1911 to 1914 he was with Brown Boveri, Baden, Switzerland. He became Secretary, and later Director, of the Société Industrielle d'Energie Électrique and took part in industrial electrical schemes in numerous towns throughout Europe. He was a consulting engineer for many organizations, including Tramways de Vienne et de Madrid, Centrale de Libau (Lettonie) and the Compagnie d'Électricité de Varsovie. He was Administrature Délégué of the latter, and also of the Société Continentale de Traction et d'Éclairage par l'Électricité.

He later turned his activities towards the administrative and financial fields, with the Compagnie Financière Industrielle, of which he remained Administrateur until his death.

He is survived by his widow.

M. Mathieu joined The Institution as a Student in 1909 and was elected an Associate Member in 1910 and a Member in 1937.

J. M. M.

ARTHUR ERIC SMITH

Arthur Eric Smith, B.SC.(ENG.), was born on 13th July 1886 at Tipton, Staffordshire, and died on the 4th May 1958 after a very brief illness. He was educated at King Edward's School, Birmingham, and served an apprenticeship with Belliss and Morcom, Birmingham. He was an outstanding apprentice and was awarded a scholarship by Belliss and Morcom with which he attended Birmingham University, although he graduated a B.Sc.(Eng.) as an external student of London University.

After graduating in 1911, he obtained an appointment as assistant engineer with the Frontino and Bolivia Gold Mining Co., Colombia, South America, with whom he stayed until the outbreak of the 1914–18 War, when he returned home and was commissioned in the South Staffordshire Regiment. He was wounded in action and on recovery was transferred to the Special Brigade of the Royal Engineers which was then being formed, and spent the remainder of the war on gas service with this unit.

After demobilization he went out to Pernambuco as assistant engineer to the Tramways and Power Co., but after a short period returned home and began his long association with Mr. Harry Astbury, subsequently entering into partnership and specializing in instruments and control gear.

Mr. Smith was quiet and unassuming but very able and was greatly liked by all his associates and people with whom he made contact in the course of his work. His main hobbies were archaeology and history. He was a strong churchman and gave much of his time to service on scientific and academic committees. He was a Past-President of the Birmingham Association of Mechanical Engineers and an Associate Member of The Institution of Civil Engineers. He joined The Institution as an Associate Member in 1924 and was elected a Member in 1943.

Mr. Smith is survived by his widow and two married daughters.

F. C. P.

LIBRARY ACCESSIONS

**Denotes that the publication is also in the Lending Library. The publications cannot be bought through The Institution; the publishers and the prices are given only for the convenience of members*

BOOKS

ALMAN, M. (Editor) 02

Aslib Directory. A Guide to Sources of Information in Great Britain and Ireland. Vol. I, Indexes and Appendixes. pp. xix, 179. Vol. II, Directory of Libraries and Information Services. Regional Index. pp. 1018

London, Aslib, 1957. 25 × 19 cm. £6 6s. (2 vols.)

Gives details of over 3000 British libraries and information departments. These are listed regionally and referred to in name and subject indexes.

BELCHEM, R. F. K. 621.039

A Guide to Nuclear Energy*

London, Pitman, 1957. pp. vii, 77. 19 × 13 cm. 10s.

Explains for persons with limited specialist knowledge how nuclear reactors function and gives a general description of the more important types. It includes a description of the constructional materials being used.

GRAY, H. J. (Editor) 53(03)

Dictionary of Physics

London, Longmans, Green, 1958. pp. x, 544. 25 × 15 cm. £4 4s.

A number of well-known authorities have contributed to the compilation of this work, which includes entries for the materials which occur in physical work and was reviewed in the June Journal (p. 331).

LAMBE, C. G. 517

Applied Mathematics for Engineers and Scientists*

London, English Universities Press, 1958. pp. xii, 518. 22 × 14 cm. £2 2s.

Covers dynamics, statics, hydro-mechanics and wave motion and is suitable for students taking Part II of the London B.Sc. General Degree examination. It is a modern treatment including, for example, under the heading of the oscillation of particles, discussion of electric circuits and servomechanisms.

LIBRARY ACCESSIONS (*continued*)

LEVELL, D. A. 621.374

Pulse and Time-Base Generators*

London, Pitman, 1958. pp. x, 175. 19 × 13cm. 25s.

A thorough, yet concise, survey of the theory and design of circuits used to generate pulse and time-base waveforms. Includes pulse modulators, trigger circuits, electromagnetic time-bases and transistors.

PHISTER, M. 518.5

Logical Design of Digital Computers*

London, Chapman and Hall, 1958. pp. xvi, 408. 23 × 14cm. £4 4s.

An introduction to such techniques as the Veitch-diagram method of simplification of Boolean equations, the difference-equation approach to memory elements, and the complete solutions of flip-flop input equations. This book will be reviewed in a future issue.

MONOGRAPHS AND PAPERS
published individually this month

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MONOGRAPH

A Method for Testing and Establishing the Rating of Semi-Conductor Rectifiers under Dynamic Conditions *Monograph* 310 M

J. I. MISSEN, M.SC.

OWING to the combination of high current density and low forward-voltage drop in the rectifying junction of a semiconductor rectifier, the physical size and thermal capacity for a given rating are low, so that the current on overload can be much greater than for other types of rectifier. Consequently, the junction-temperature rise on overload is extremely rapid, and in some cases large temperature fluctuations occur at mains frequency. It is therefore necessary to be able to monitor the junction temperature dynamically (i.e. in working conditions at mains frequency) and to observe the rate of increase of temperature. A further necessity for dynamic testing arises from the fact that the measurement of the forward characteristic at high current by d.c. methods can result in excessive heating and possible failure. In the apparatus described, the separation of forward and reverse half-cycles is secured by means of a synchronous commutator, permitting independent measurement of forward and reverse currents and voltages at mains frequency, and hence continuous indication of junction temperature. Operation of the rectifier at full rating without expenditure of the full power needed to accomplish this by direct methods is also possible. This is particularly useful in life-testing large numbers of semiconductor rectifiers. Limited experience indicates that this method of testing provides operating conditions in all ways identical with those which a device experiences under full load.

PAPERS

Electrification of the U.K.A.E.A. Industrial Group Factories *Paper* 2698 U: *Part A*

J. W. BINNS *and* W. J. OUTRAM, M.ENG.

THE paper describes some of the special electrical requirements and problems at the various factories of the Industrial Group of the United Kingdom Atomic Energy Authority. It deals with the three main groups of the Authority's activities, i.e. chemical plants, diffusion plant and nuclear reactors.

The authors discuss the need for a high standard of cleanliness and ventilation everywhere, but particularly in chemical plants; the maintenance of cooling systems and safety circuits for reactors; and some of the special electrical-supply problems in diffusion plants.

The Authority's general policy on standardization, electrical safety, etc. is stated.

Electrical Installation at Calder Hall Nuclear Power Station *Paper* 2699 U: *Part A*

N. J. MACKAY *and* E. HARDWICK

THE paper describes the essential features of the installation, with particular regard to the security of the supplies to the reactors. Main connections to the Grid system and the method of electrical control are considered.

Particulars are given of the electrical equipment required for normal operation of the reactors and for emergency operation on failure of the main supply. The method of change-over from normal to emergency running is explained in some detail, since it affects the safety of the reactor and must be reliable.

The authors briefly outline the way in which some of the special problems were approached and indicate the reasons for adopting a particular solution.

SOME RECENT BOOKS

R. DORFMAN, P. A. SAMUELSON AND R. M. SOLOW

LINEAR PROGRAMMING AND ECONOMIC ANALYSIS

MCGRAW-HILL. 1958. 525 PP. £3 17S. 6D.

THE term *linear programming* has come into use for the process of solving certain kinds of problems of maximization: but this book is more than an account of these processes, it brings some central problems in theoretical economics within their scope. It is an important contribution to economic theory.

The first half of the book is a remarkably lucid account of what is meant by linear programming and of the arithmetical procedures used in these processes. The method of exposition is to consider a number of real problems (very happily selected), to discuss the problem in simple common-sense terms, and to introduce the minimum necessary mathematics in a natural way in seeking the solution of progressively more complex problems.

The first problem so discussed is the classical one of choosing a diet of minimum cost from given foods to meet minimum dietetic requirements for stated constituents.

The topic in general is a peculiarly awkward one for exposition, and the mathematics is not all easy, but the authors have succeeded in being clear and interesting where a more formal treatment might have produced a book that would repel all but hardened mathematicians. As a result, the concepts and the practical use of the methods described are opened up to economists and industrial engineers.

An excellent account of matrix algebra is added as an appendix, which relates matrices to space-vectors from the start, and which will therefore be very useful to students.

In the latter half of the book the discussion is carried forward into much more general fields, and in particular to the discussion of general economic equilibrium. The condition that in economics there are many quantities that cannot be negative is not to be disregarded. When this condition exists together with a requirement for maximizing some quantity, the problem is within the field of linear programming.

The book concludes with an explanation, having the same admirable clarity, of the 'Theory of Games', in the sense of Von Neumann and Morgenstern. The inclusion of part of the theory of games in a book on linear programming is fully justified by the authors' showing that the problem of selecting a 'strategy' to maximize probable returns is mathematically identical with a linear-programming problem in the case of the 'two-person zero-sum' game (i.e. where one gains what the other loses).

This brief mention of some of the contents of this book gives a less than adequate impression of the wealth of ideas and of the potency and interest of the great many theorems developed in its pages. It is a highly stimulating work, which will provoke the application of the methods it describes in wide and varied fields. There is great scope for their useful applications, for example, in the engineer's problem of the optional design of machinery and physical systems.

It is a book in every way worthy of its distinguished authors.

A. I. KHINCHIN

MATHEMATICAL FOUNDATIONS OF INFORMATION THEORY

CONSTABLE. 1958. 120 PP. 11S.

IT MIGHT be argued that at least this book justifies The Institution's policy of resisting any reduction in the mathematical requirements of an engineering education. For although it is offered to communication engineers among others, the second part assumes familiarity with the notation of set theory and the properties of a Borel field: and this at a time when British authors dare not publish an engineering book using Laplace transforms without a detailed explanation. To some extent this argument is correct, for the mathematical equipment required by engineers is steadily increasing in extent. But the engineer (even the communication engineer) may justly retort that Khinchin is a professional mathematician and that this book is in fact a reprint in translation of two papers originally published in a Russian journal of mathematics. Since the translators offer no foreword, one can but blame the publishers for the statement inside the cover that this highly mathematical treatise offers a lucid, comprehensive *introduction* to the rapidly growing field of information theory. The publishers also appear to take a narrowly national view in suggesting that only one other book has been published between that of Shannon and Weaver and the present book: at least two have been published in Britain, besides one in the United States.

As to the actual content of the book, one is struck by the contrast in mathematical arduousness between the two parts, as well as by the fact that the first section of the second part is largely a recapitulation of the first part. The discussion of 'The Entropy Concept in Probability Theory' which constitutes the first part is so lucid and moderate in its demands on the mathematical ability of the reader that it might almost serve as an introduction to the subject, though it does not adequately deal with the sign relationship between 'entropy' and 'information'. When the author regards entropy as a measure of 'the amount of information obtained in moving ahead r steps in the [Markov] chain', he does not make it clear whether he is referring to r steps at the transmitting end, which generate entropy, or to r steps in the decoding process at the receiving end, which annul entropy and reveal information.

The discussion of entropy occupies 28 pages, but the following 90 pages on 'The Fundamental Theorems of Information Theory' are of a different character. It is here that set theory is introduced, and although the mathematics are not intrinsically difficult, the proofs are of necessity tedious because they are meticulously rigorous; and they appear the more esoteric from the use, for example, of Doob's concept of the martingale.

The translation is so good that one is unaware that it is not the original language until the German word *Satz* unexpectedly appears at the foot of p. 72, and on p. 79 that difficult word *random* appears to be used to indicate that chance intervenes to some extent, although the result is not entirely lacking in systematic relationship.

Engineers will be tempted to regard this work as analogous to a birth certificate: evidence which one produces if challenged

to prove the legitimacy of something which normally is taken to be accepted fact. For this purpose the book is a useful addition to the engineer's bookshelf.

A. G. KOROL
SOVIET EDUCATION FOR SCIENCE AND TECHNOLOGY

NEW YORK: JOHN WILEY. LONDON: CHAPMAN AND HALL. 1957. 513 PP. £3 8S.

ALEXANDER KOROL's survey of Soviet education provides a useful companion volume to de Witt's 'Soviet Manpower'. It contains much additional information about courses, syllabuses and examination papers, and anyone seriously interested in Soviet education will find it a valuable work of reference.

It is written around information collected and annotated with typical American thoroughness and with the care and precision of a photographic survey over enemy country in war time. The information so collected is sharply in focus and correctly pieced together, but while it gives a composite picture it cannot tell the whole story. It provides us with much information about our aloof Russian neighbours, but it is still no substitute for a personal visit and a personal assessment of the levels of attainment in the courses and examinations or of the enthusiasm and industry of the students.

Comparisons with American levels of attainment are attempted in many places in the book, but the English reader will find little assistance in these comparisons unless he has already an intimate knowledge of the very complex system of American education with its widely varying aims and widely varying standards of achievement. The report of the British team which visited Russia in Autumn 1956, entitled 'Engineering Education in the Soviet Union', may be more helpful here.

A chapter is devoted to the work of 'Technicums', and comparisons are made with the American technical institutes; but it would appear that the author has not fully appreciated the significance of the Technicum's contribution to the future Russian effort in providing a force of trained technicians to support the professional engineers in industry. It is the Russian aim to have three technicians to support each professional engineer.

The British system of a broad technical education and a period of practical training followed by engineering experience in a specialized field in association with a practising professional engineer is unknown in Russia and is probably unattainable there. As an alternative, the final two years of the work in the institutes and polytechnics for higher education are devoted to specialization in some branch of applied engineering, so that the student is able to take his place in a design team or an operational organization immediately on entering industry. Many visitors to Russia and to the Continent are attracted by the apparent efficiency of this arrangement, although it is achieved by some sacrifice of the basic principles of engineering science and requires that the student's future career shall be determined early in his technical training before he has had an opportunity of personal knowledge of the industry he is to serve. The constant references in the book to the attention now being given to practical experience is of particular significance, and there are proposals that in future the Russian engineering diploma should be presented only after a period of experience in industry following the completion of the course at the institute or polytechnic.

The difficulties facing the Soviet Executive in carrying through its plans for a secondary education for all children in Russia up to the age of 17, while still restricting the places available in the universities, institutes and polytechnics for higher education, are well brought out; and these difficulties probably account for the proposed extensions of part-time and correspondence courses. It would appear that the Russian requirements will in general be met by an increase from 200 000 to 300 000 in the places in higher educational institutes but that the part-time and correspondence courses are to be greatly expanded to give everyone an opportunity to study at the higher level, even though the courses are hard and the failures are many.

W. K. MANSFIELD (*Editor*)
NUCLEAR ENGINEERING MONOGRAPHS

1 ELEMENTARY NUCLEAR PHYSICS. 60 PP. 10S. 6D.
2 NUCLEAR REACTOR THEORY. 80 PP. 12S. 6D.
3 REACTOR HEAT TRANSFER. 68 PP. 10S. 6D.

TEMPLE PRESS. 1958

THESE three volumes are the first of a total of six covering the general field of nuclear engineering. The series is officially aimed at university and technical-college students, research assistants and qualified technicians who require a broad understanding of those topics of nuclear engineering lying outside their own field of study.

The reader of this review will naturally wish to know whether this aim is achieved. Comparing all three books with other specialist works currently available, the former present facts much more concisely, and this might be said to summarize the measure of their achievement. They are priced accordingly.

Because of their conciseness there has had to be some sacrifice of depth of treatment, and of explanatory detail.

In Vol. 1, 'Elementary Nuclear Physics', some steps in reasoning are rather too big; for instance, it is not easy to see why a salt crystal expands on heating, although this is supposed to be immediately deducible from the diagram belonging to the section on ionic forces. In the chapter on neutron physics the thermal-fission factor η is defined but not the infinite reproduction constant k_∞. However, despite weaknesses in detail of which these are typical examples, much information is presented in a very helpful way. The chapter on radiation detectors is comparatively detailed and useful either for students or for those who have daily contact with such apparatus.

Vol. 2, 'Nuclear Reactor Theory', can be compared in scope with chapters 6–10 and 12 of 'An Introduction to Reactor Physics' by Littler and Raffle. It covers the subjects of neutron diffusion and neutron chain reactions with a detailed exposition of most of the developments in this subject, e.g. Westcott flux convention, flux discontinuity across the gas-coolant channels surrounding fuel elements, and diffusion asymmetry due to these coolant voids. The work ends with a brief but lucid exposition of some of the problems involved in power operation and the economic use of fuel. With certain reservations, based on the degree of condensation which has been necessary, the advanced student can accept the book as providing most of the formulae necessary for calculating the nuclear characteristics of a hot, poisoned power reactor under time-independent conditions.

Vol. 3, 'Reactor Heat Transfer', is characterized by a clear, concise and very readable style. The division into three sections, namely fundamental theory, application of theory

to reactor-core cooling, and miscellaneous problems, will be of particular value to the reader who, according to the extent of his fundamental knowledge, may or may not wish to read the first section. Some comparison might have been made with advantage of the various types of extended surface. This publication should be of great use to anyone interested in obtaining a general picture of the processes involved in removing heat from a reactor core.

Of the series as a whole, its principal contribution is to digest information which by and large has already been published. Like previous collections on different aspects of nuclear engineering, the books tend to give the impression of having been written by a number of experts in watertight compartments. In commercial nuclear engineering this problem is overcome by means of a project engineer covering the whole field. Similarly, such a series of writings should start with a volume dealing with the general principles of attack on a commercial reactor-design project. The specialist books should be written after the authors have been given an opportunity of reading the draft of the first work, so that they can key into the introductory volume.

G. C. NEWTON, L. A. GOULD AND J. F. KAISER
ANALYTICAL DESIGN OF LINEAR FEEDBACK CONTROLS

NEW YORK: JOHN WILEY. LONDON: CHAPMAN AND HALL. 1957. 419 PP. £4 16S.

G. L. MURPHY
BASIC AUTOMATIC CONTROL THEORY

VAN NOSTRAND. 1957. 557 PP. £3 7S. 6D.

NEWTON, Gould and Kaiser's book is the first to be published giving a comprehensive exposition of the application of Norbert Wiener's generalized Fourier analysis to the design of automatic-control systems. Although Wiener developed the theory more than 15 years ago, it has never been used much by engineers, partly because of the mathematical difficulty and partly because it was found to give trivial or unsatisfactory solutions. We now know that this was because it was improperly used, and Newton was the first person to show how it could be applied to systems with limited power output, which opened the way to its proper use.

The authors of this work start where the ordinary linear theory of automatic control leaves off; and after a brief review of the elementary principles of control and what they call the trial-and-error methods of design, they start from Parseval's theorem and proceed to describe the analytical methods of designing systems for optimum performance. Although not generally appreciated, it is now known that these analytical methods are generally applicable and, used intelligently, will almost always give the optimum design to meet any given condition better than the trial-and-error methods. Unfortunately, the mathematics is still tedious, but computations carried out in the Engineering Department of Cambridge University show that charts can be prepared which it is hoped will relieve engineers of tedious computation. The authors are therefore right to relegate the trial-and-error methods as well as the underlying mathematics of control-system theory to appendices.

The minimization of error procedure is first applied to systems with determinate inputs and is later, after some discussion of stochastic processes, applied to systems with random inputs. The full treatment of systems with both random input and unwanted noise and fluctuations appearing at different parts of the system is not developed; but there is some discussion of this problem, and a method is given of limiting the bandwidth of the system to reduce the effect of noise. The authors seem to have failed to realize that, provided that a power constraint is applied to a system with both a random input and noise, their method of optimization automatically specifies the appropriate bandwidth for the optimum reduction of the effect of noise on the output. In some cases their method of obtaining the appropriate bandwidth limitation may be more suitable, but the calculations being carried out at Cambridge, mentioned above, indicate that the relationship between mean-square error and average power output is almost certainly the best criterion for determining the appropriate bandwidth of the system.

Examples of practical systems are not discussed in the earlier parts of the book, but the method is applied to a practical problem, that of the control of a radio telescope, in chapter 9. The 'pros and cons' of analytical design compared with trial-and-error methods are very well set out in this chapter, and the difficulties of the analytical method are discussed without bias. This example, which takes into account the effect of wind gusts on the very large paraboloid to be controlled, involves an estimate of the effect of wind gusts, which is a fine example of intelligent guess-work, completely justified as being the only method of obtaining a reasonable solution. The whole exposition is exceedingly clear and readable, and certain concepts, such as the distinction between mean-square value and power spectrum and the relationship between the spectral densities of the output and the input signal, are very clearly set out.

There appear to be very few misprints, but on p. 120 there seems to be some confusion between differentiating and integrating networks. In chapter 8, the authors seem to imply that, provided that the fixed elements are minimum phase (in the Bode sense), they do not affect the solution and can therefore be ignored in the optimization procedure, even when noise is present. This is incorrect: they can, of course, be ignored when there is no noise, because their effect can always be eliminated by the inclusion of an inverse network; but when there is noise present this does not apply, and they must be taken into account in the optimization procedure.

It is perhaps fortunate that another publishing house should at approximately the same time have released a book on the ordinary linear theory by Gordon Murphy, which is almost exactly complementary to the first work. Mr. Murphy's book deals with the linear theory, which leads up to the point at which the other volume begins in a manner which is leisurely, readable and easily understood. These two books together, therefore, provide the student of control-system design with a very complete explanation of the methods of dealing with linear systems.

K. RAWER
THE IONOSPHERE

CROSBY LOCKWOOD. 1958. 202 PP. £2 2S.

THE AUTHOR of this excellent book, who is well known for his work on ionospheric propagation, has given special consideration to the interests of the radio engineer. The subject is introduced by a section dealing with the sounding of the ionosphere by radio waves, while the final chapter is devoted to the influence of the ionosphere on radio communication and discusses the calculation of field strengths and the prediction of propagation conditions. In the first chapter other methods

of obtaining information about the ionosphere are reviewed, including the study of aurorae, meteors, noctilucent clouds and the light of the night sky, geomagnetic and spectroscopic observations, and direct physical measurements made in rocket ascents.

There follow chapters presenting the observational results and the theories based on them of the processes of ionization and the formation of the various layers. The final chapter is preceded by a description of the regular daily and seasonal variations in the ionospheric layers and of the irregular phenomena of sudden ionospheric disturbances, magnetic storms and solar eclipses.

The style is free and easy to read, but the account of the ionosphere is by no means self-contained and can only be fully appreciated by those already acquainted with the subject or who are prepared to follow up the many references given.

On the other hand, it is one of the great merits of the book that the author has so ably summarized the vast literature about the ionosphere. By his skilful references to the comprehensive bibliography, he has provided the reader with much valuable direction in the formidable task of consulting and assessing papers in the scientific journals.

It is unfortunate that in this welcome translation the language is here and there ungrammatical and ambiguous and a number of obvious misprints have escaped correction. It is also a pity that, in preparing this English text for publication five years after the original German edition, more opportunity was not taken to bring one or two matters up to date. In particular, the reference to forward scattering is still brief in the extreme, while no mention is made of 'whistlers' and the theory of their propagation through the ionosphere at very low frequencies.

However, these are minor criticisms. The book will be of great interest to the general reader and of particular value to the specialist in one part of ionospheric research who seeks guidance in improving his knowledge of the whole field.

SIR ROBERT WATSON-WATT

THREE STEPS TO VICTORY

ODHAMS. 1958. 480 PP. 30S.

TO THOSE who were engaged during the war in the development and application of radar to the problems of air defence this book will be of great interest from both the technical and operational points of view.

In those days of stress and fear it was impossible for people at the working level to see the general picture of radar development in this country and the manner in which political, military and engineering interests had to be reconciled in building up an effective air-defence organization.

Sir Robert's book provides an intimate and exciting picture of these processes at work, and if the emphasis is perhaps a little too strong on his own contribution, it is an understandable fault in one who was the principal architect of the radar-defence organization.

Whether the book will be of interest to the general reader, or even to those who are scientifically inclined but who have not been themselves connected with radar, is very doubtful, and for this the pattern of the book itself is to blame. As is explained in the foreword, the book began as an autobiography, but the theme of Watson-Watt could be sustained only by bringing in the history of radar; if the interest in radar is lacking in the reader, only the story of the politico-military growth of radar air defence will rescue the book from condemnation.

The author's dedication to the task of defending Britain against air attack by building a radar screen shines through the obscurity of presentation. Many of the quips and sallies which the author interjects into a serious story are vastly entertaining, but only too frequently they serve to divert the reader from the important point at issue and produce a feeling of irritation with a text that is witty, erudite, complex and egotistical.

The author has a marvellous story to unfold, but it would have gained by simplicity in presentation; and it could well have included more references to parallel work in other countries and more detailed description of radar applications other than the building of the great CH chain.

Contents of the Current Issues of the *Proceedings*

The date in italics is that of the Journal review or special article. Where given, the date in capitals refers to the month in which a paper was published individually

PART A. POWER ENGINEERING (AUGUST 1958)

B. C. ROBINSON, M.SC., PH.D., AND A. I. WINDER. PAPER NO. 2456 U, DECEMBER 1957 **Supply-Voltage and Current Variations Produced by a 60-Ton 3-Phase Electric Arc Furnace** *June 1958*

JEAN PIMPANEAU. ABSTRACT NO. 2558 **The Planning and Construction of Large Modern Thermal Generating Stations**

P. RICHARDSON. PAPER NO. 2492 S, JANUARY 1958 **Design and Application of Large Solid-Rotor Asynchronous Generators** *June 1958*

F. BUSEMANN, DR.ING., AND W. CASSON. PAPER NO. 2575 S, FEBRUARY 1958 **Results of Full-Scale Stability Tests on the British 132kV Grid System** *June 1958*

F. H. LAST, PH.D.(ENG.), B.SC.(ENG.), E. MILLS, AND N. D. NORRIS. PAPER NO. 2559 S, FEBRUARY 1958 **Organization for Large-Scale Grid-System Tests** *June 1958*

PROF. H. BLOMBERG, D.SC., AND P. J. KARTTUNEN, M.SC. PAPER NO. 2482 M, JANUARY 1958 **A Ferrometer for the Determination of the A.C. Magnetization Curve and the Iron Losses of Small Ferromagnetic Sheet Samples** *August 1958*

J. MCFARLANE, B.SC., P. MILNE, AND J. K. DARBY, B.SC.(ENG.). PAPER NO. 2553 M, FEBRUARY 1958 **Direct-Reading Iron-Loss Testing Equipment for Single Sheets, Single Strips and Test Squares** *August 1958*

J. M FARLANE, B.SC., AND M. J. HARRIS, B.SC. PAPER NO. 2554 M, FEBRUARY 1958 **The Control of Flux Waveforms in Iron Testing by the Application of Feedback Amplifier Techniques** *August 1958*

Discussion on **Choice of Insulation and Surge Protection of Overhead Transmission Lines of 33kV and Above** before the North Midland Centre and the Northern Ireland Centre

PROF. G. H. RAWCLIFFE, M.A., D.SC., R. F. BURBIDGE, B.SC., PH.D., AND W. FONG. PAPER NO. 2597 U **Induction-Motor Speed-Changing by Pole-Amplitude Modulation** *August 1958*

A. S. ALDRED, M.SC., AND G. SHACKSHAFT, B.ENG. PAPER NO. 2662 S **The Effect of a Voltage Regulator on the Steady-State and Transient Stability of a Synchronous Generator** *June 1958*

J. H. WALKER, M.SC., PH.D., AND N. KERRUISH, M.A. PAPER NO. 2678 S **Design of Fractional-Slot Windings** *June 1958*

J. P. PITTS, B.SC.(ENG.). PAPER NO. 2664 **Capacitors for Discharge-Lighting Control Circuits** *August 1958*

PART B. RADIO AND ELECTRONIC ENGINEERING (JULY 1958)

See the Journal for July 1958, p. 404

PART C. MONOGRAPHS (MARCH 1958)

See the Journal for March 1958, p. 158

Reconstruction of the Institution Building

IN the Report of the Council presented at the Annual General Meeting on the 15th May last there is an outline of the position which had then been reached in the planning of the reconstruction of the Institution building (see par. 23 on p. 363 of the July *Journal*). As mentioned by the President at that meeting (see p. 355), the period since the broad proposals were approved at the Special General Meeting of members in June 1957 had been used to examine closely the details of the plan and the method of carrying it out, and as a result certain economies have been found possible. In addition, the preliminary negotiations with the Duchy of Lancaster for a new ground lease have since been concluded. The Council, at their meeting in June, decided that the way was now clear to commence the Reconstruction Scheme within the limits of present resources, and they gave authority for tenders to be invited for the first phase (third floor) and for a formal application to be made to the Duchy for the grant of the new lease.

On completion of the first phase the remainder of the Building Fund will be used for selected parts of the second phase, so that there can be some much-needed improvement in the public sections of the building for the time being, until completion of the full scheme becomes possible.

An architect's drawing showing the final external appearance of the building was reproduced on p. 354 of the June 1957 *Journal*; it will be seen from this that windows will be added to the top floor and that the front elevation of the ground floor will be changed. The revised plan will not materially affect the facial appearance of the building. Members may also like to look again at the drawing of the larger Lecture Theatre which appeared in the same issue and at the ground-floor plan shown on p. 638 of the December 1957 *Journal*.

Planning of the reconstruction as a whole requires that a start must be made on the third floor in the first phase of the work because removal of the services now housed in the basement up to the third floor is a necessary step before certain parts of the second and third phases of the scheme can be undertaken. Furthermore, by taking over and making suitable for Institution purposes the premises which are about to be vacated by the tenants on this floor, a considerable increase in space will be obtained, not only for urgently required office accommodation but also for use as an emergency additional meeting room.

TECHNICAL PUBLICATIONS

BRITISH STANDARDS

Copies of the following publications can be obtained from the British Standards Institution, 2 Park Street, London W.1. The prices given are post free.

B.S. 1933: Part 2: 1958 **Varnish-Bonded Glass-Covered Copper Conductors: Rectangular Conductors.** 5s.

WITH the publication of this part, the scope of B.S. 1933 has been extended to deal with rectangular conductors as well as round wire. Double glass coverings only are specified for rectangular conductors, in three standard thicknesses. The qualitative requirements and the tests are similar to those for round wire.

While it has not been possible to adopt standard sizes for rectangular conductors, this new publication includes a schedule of preferred sizes.

B.S. 2990: 1958 **Rationalized and Unrationalized Formulae in Electrical Engineering** 4s. 6D.

THE M.K.S. rationalized system of units is being used increasingly by electrical engineers, and its adoption has been recommended by the International Electrotechnical Commission and The Institution. The C.G.S. systems, with which many engineers became acquainted during their education, are, however, still to be found in technical literature. This Standard therefore gives the more important relations in electrical science in both the rationalized and the unrationalized systems. The information is expressed in tables and explanatory notes and includes examples of 'defining' relations; qualities unaffected by rationalization; and qualities affected by rationalization. B.S. 2990 supplements B.S. 1637, 'Memorandum on the M.K.S. System of Electrical and Magnetic Units'.

CENTRAL ELECTRICITY GENERATING BOARD

Cathodic Protection of Buried Structures

THE method, known as cathodic protection, of inhibiting corrosion of pipes, cables, etc. buried in the ground, has certain complications, in that soil currents so caused may stray to, and affect electrochemically, adjacent metallic objects.

The Joint Committee for the Co-Ordination of the Cathodic Protection of Buried Structures was set up in December 1953 to examine the possibility of harmful interference and its limitation. This recently issued pamphlet describes the genesis and aims of the Joint Committee and the progress so far made.

A summary of electrochemical principles includes a table outlining methods of preventing corrosion, although a foreword states that the information given about practical methods is for illustration only, and not intended as a technical guide. The application of cathodic protection, the severity of interference, and the direction of research are dealt with.

The constitution of the Joint Committee and of its associated Technical Panel is given at the end of the pamphlet, which can be obtained free of charge from The Central Electricity Generating Board, 24–30 Holborn, London E.C.1.

Medical Electronics

From a Special Correspondent

AN international conference on medical electronics, sponsored by the Council of International Organizations of the Medical Sciences (formed under the aegis of Unesco and the World Health Organization) and the Rockefeller Institute for Medical Research, and instigated by Dr. V. K. Zworykin of the Rockefeller Institute of Medical Electronics, was held in Paris from the 26th to 28th June under the Presidency of Prof. Fessard and the Vice-Presidency of Dr. Maurice Marchal.

The presence of 60 delegates, unofficial representatives of nine countries—including Japan and Brazil, was a tribute to the growing importance of the subject and to the personality and achievements of Dr. Zworykin. Nine British representatives attended as observers after discussions arranged by The Institution's Joint Panel on Radiological and Electromedical Apparatus, which comprises members of the medical, as well as of the electrical engineering, profession.

It was Dr. Zworykin's contention that medicine as a whole is not taking full advantage of the electronic aids now available, and that new developments could be employed to assist both research and the efficiency of practice. Some papers presented at the conference, and summarized below, illustrate this contention.

The magnitude of the tasks envisaged, in terms of money and labour, makes it essential that there should be well co-ordinated planning of projects. This can be achieved by the formation of national and international committees on which doctors and electrical experts are equal partners, and where the scientist and engineer provide the apparatus and leave the interpretation and application of results to the medical profession.

Those present at the conference formed themselves into an interim committee and interim executive council with four objectives:

1. To encourage the formation of national committees, representative, if practicable, of their learned societies

2. To arrange a further international conference for Paris in June 1959

3. To assist in the preparation of an international bibliography of medical electronics, as already started by the Rockefeller Institute

4. To draft a constitution for an international body and consider formal association with Unesco (C.I.O.M.S.). Approval would be sought following discussion at the next international meeting.

The interim executive officers are: V. K. Zworykin (U.S.A.), *President*; M. Marchal (France), *Vice-President*; C. N. Smyth (G.B.), *Vice-President and Chairman of Publications Committee*; B. Shackel (G.B.), *Treasurer*; C. Berkley (U.S.A.) and A. Remond (France), *Secretaries*; Prof. Sakomoto (Japan), Prof. O. Wyss (Switzerland), and Dr. Bekkering (Holland), *Advisers*.

It may well be that The Institution's existing Joint Panel on Radiological and Electromedical Apparatus will provide a convenient basis for an eventual British National Committee on Medical Electronics, whether or not a continuing international organization finally emerges. Members wishing to co-operate in this work are asked to communicate with the Secretary.

Report of Conference

Electronics as a catchword has been much abused; but now that Dr. V. K. Zworykin, that brilliant harnesser of the electron, has formed a Medical Electronic Unit at the Rockefeller Institute for Medical Research and instigated an international conference on the subject of *medical electronics*, we must accept that a branch of science and engineering has come to the assistance of medicine under this name.

Dr. Zworykin, not content with having pioneered modern television, the electron microscope, the image convertor, the photomultiplier, and traffic-control systems, has in his official retirement produced the ultra-violet television colour-translating microscope and a 'radio-pill' which after being swallowed transmits by radio signals the 'pressure' or pH-value within the intestinal canal.

The Paris conference did not give the impression that there was a monopoly in this field. Among the 34 papers presented were many of considerable interest. To report a few is not to slight the rest.

Dr. M. Marchal and his colleagues from the Hôpital St. Antoine, Paris, surprised everyone with their 'Cinédensigraphie'. The peripheral parts of organs, for example the lungs or liver, vary in their opacity to X-rays with each respiratory and cardiac cycle. The variations can be recorded by a small roentgen dosemeter placed behind the patient. The recordings provide information on air entry and vascular mobility which is of value in locating the boundaries of neoplastic changes and chronic diseases. This test has been used for the differential diagnosis of primary and secondary neoplasms of the lung, chronic bronchitis and emphysema, thrombosis, and tricuspid valve disorders.

Dr. Stuart Mackay from California described pressure-sensitive paint for the construction of manometers for internal use. Pressure causes the paint layer to change electrical resistance between surfaces, which must be coated with metal.

Dr. Zworykin gave technical information on his ultra-violet colour-translating microscope.

From the British side, Dr. P. Bauwens spoke of advances in electrodiagnosis, Dr. R. E. George dealt with transistor techniques for electromyography, and Dr. B. Shackel introduced us to ergonomics with a paper on ocular co-ordination. Dr. C. N. Smyth described the ultrasonic telescope with which he hopes eventually to visualize the foetus *in utero* and the heart valves in action.

Perhaps the most popular subject was introduced by Dr. Carl Berkley (Rockefeller Institute) and M. le Guendal (France), namely the use of electronic computers in medical research and practice. The computer, with its punched-card, magnetic tape or photographic store of coded information, can classify and select medical literature automatically. Once a machine is allocated to this purpose and systematically fed with classified abstracts of papers, the preparation of bibliographies of single subjects or of combinations of subjects or of details of content is an effortless process. What can be done for a library can also be done for patients' records, and later case-histories can be added to former records and the changes tabulated.

Dr. Berkley's computer has been programmed for the diagnosis of haematological diseases. Coded information,

received for example by telephone, of a patient's symptoms, signs and laboratory findings, is passed to the computer. A few moments later, a typed form lists the changes in the patient's state since the last entry, gives the differential diagnosis, and enumerates the tests necessary to make the diagnosis positive. Any excess information is recorded in case a multiple diagnosis is necessary.

It is only one step further for the computer to define the best treatment (from its own previous experience?) and provide a list of suitable diagnostic laboratories and, if desired, the name of a specialist who, freed from the chores of his task, can concentrate on further research or the doctor/patient relationship! There is still work for the consultant when patients who feel poorly have no clear symptoms or signs!

There was some informal discussion on the possibilities of paramagnetic and nuclear resonance methods for investigation and treatment at specific chemical levels, since nuclear resonance can be applied to chosen molecules with specific neighbourly relations.

The conference showed that many medical research workers are spending their lives on circuit research and design of instruments. In this they are often repeating industrial work or struggling with problems that a trained electrical engineer could solve speedily. Co-operation through the personal contacts that conferences provide, whether national or international, or through a computer-controlled index, can free such workers for their primary task of biological research.

There is surely now a good case and opportunity for planning authorities to get together and determine what is necessary and desirable, where work should begin, and by what means it should be financed.

ANNOUNCEMENTS TO MEMBERS

THE HOMES FUND

SUMMARY OF CONTRIBUTIONS RECEIVED TO 22ND JULY 1958

	No. of Contributors	£	*s.*	*d.*
£1000 and over	6	6000	0	0
£100 to <£1000	30	6586	3	0
£5 to <£100	856	9080	16	7
£2 to <£5	2078	5691	13	11
Under £2	24115	12504	18	2
	27085	£39863	11	8

AWARD OF PREMIUMS

THE Council have awarded the following premiums for papers read or accepted for publication during 1957. Previously, premiums have been awarded for the 12 months ending during May in each year, but the period has now been changed to the calendar year. These awards for 1957, therefore, cover a space of approximately eight months only. The awards for 1958 will cover the full calendar year.

GROUP A

The Institution Premium (value £50)
The late E. C. S. Megaw, M.B.E., D.SC. — 'Fundamental Radio Scatter Propagation Theory'

The Kelvin Premium (value £25)
G. H. Metson, M.C., PH.D., M.SC., B.SC.(ENG.) — 'The Conductivity of Oxide Cathodes. 1—Potential Distribution; 2—Influence of Ion Movements on Matrix Resistance; 3—Movements of Electrolytic Oxygen in a Conventional Diode System; 4—Electron Transfer Mechanisms'

The John Hopkinson Premium (value £25)
No award.

GROUP B

Measurement and Control Section Premiums

The Silvanus Thompson Premium (value £20)
T. Kilburn, M.A., PH.D., D.SC., G. R. Hoffman, PH.D., B.SC., and R. E. Hayes, M.SC. — 'An Accurate Electroluminescent Graphical-Output Unit for a Digital Computer'

The Mather Premium (value £15)
M. V. Wilkes, M.A., PH.D., F.R.S., W. Renwick, M.A., B.SC., and D. J. Wheeler, PH.D. — 'The Design of the Control Unit of an Electronic Digital Computer'

A Premium (value £10)
G. B. B. Chaplin, M.SC., PH.D., and A. R. Owens, M.SC. — 'Some Transistor Input Stages for High-Gain D.C. Amplifiers'
G. B. B. Chaplin, M.SC., PH.D., and A. R. Owens, M.SC. — 'A Transistor High-Gain Chopper-Type D.C. Amplifier'

Radio and Telecommunication Section Premiums

The Duddell Premium (value £20)
Prof. A. L. Cullen, PH.D., B.SC.(ENG.), and H. A. French, PH.D., B.SC.(ENG.) — 'An Instrument for the Absolute Measurement of Low-Level Microwave Power in the 3 cm Band'

The Ambrose Fleming Premium (value £15)
Prof. H. E. M. Barlow, PH.D., B.SC.(ENG.), and H. G. Effemey — 'Propagation Characteristics of Low-Loss Tubular Waveguides'

Premiums (value £10 each)
H. E. Holman, G. C. Newton and S. F. Quinn — 'A Flying-Spot Film Scanner for Colour Television'
G. H. Jonker, H. P. J. Wijn and P. B. Braun — 'A New Class of Oxidic Ferromagnetic Materials with Hexagonal Crystal Structures'
E. W. Gorter — 'Saturation Magnetization of Some Ferromagnetic Oxides with Hexagonal Crystal Structures'
B. B. Jacobsen, B.SC.(ENG.) — 'Thermal Noise in Multi-Section Radio Links'
F. H. Wells, M.SC.(ENG.), and J. G. Page, B.SC. — 'A 1000-Channel Neutron-Velocity Spectrometer Using Ferrite Data Storage'
F. H. Reynolds, B.SC.(ENG.), C. B. Johnson and M. W. Rogers — 'Growth of Anode-to-Grid Capacitance in Low-Voltage Receiving Valves'
F. H. Reynolds, B.SC.(ENG.), and M. W. Rogers — 'A New Method for the Detection of Thin Conducting Films in Thermionic Valves'
V. G. Welsby, PH.D., B.SC.(ENG.) — 'Electromagnetic Fields in a Ferromagnetic Medium, with Particular Reference to Harmonic Distortion due to Hysteresis'
H. P. J. Wijn, H. Van Der Heide and J. F. Fast — 'Ordering in Cobalt-Ferrous Ferrites'
H. P. J. Wijn and H. Van Der Heide — 'Pulse-Response Properties of Rectangular-Loop Ferrites'
W. J. Pohl, M.SC. — 'The Design and Operation of High-Power Triodes for Radio-Frequency Heating'
J. S. Seeley, PH.D., B.SC.(ENG.) — 'A Spectrometer Method for Measuring the Electrical Constants of Lossy Materials'

Cmdr. J. C. G. Field, R.N., B.SC. — 'The Design of Automatic-Gain-Control Systems for Auto-Tracking Radar Receivers'

J. M. C. Dukes, M.A. — 'The Application of Printed-Circuit Techniques to the Design of Microwave Components'

Supply Section Premiums

The Sebastian de Ferranti Premium (value £20)
No award

The John Snell Premium (value £15)
F. Mather — 'Earthing of Low- and Medium-Voltage Distribution Systems and Equipment'

A Premium (value £10)
W. A. Sharpley and J. V. Oldfield, B.SC.(ENG.) — 'The Digital Computer Applied to the Design of Large Power Transformers'

Utilization Section Premiums

The Crompton Premium (value £20)
L. Abram, B.SC.(ENG.), J. P. McBreen and J. Sherlock, B.SC.(ENG.) — 'D.C. Winder Drives Using Mercury-Arc Rectifier/Inverters'

The Swan Premium (value £15)
No award

A Premium (value £10)
E. R. Laithwaite, M.SC., PH.D. — 'Linear Induction Motors'

Non-Section Premiums

The Ayrton Premium (value £20)
No award

The Llewellyn B. Atkinson Premium (value £15)
No award

A Premium (value £10)
A. E. Guile, PH.D., B.SC.(ENG.), and S. F. Mehta, B.E. — 'Arc Movement Due to the Magnetic Field of Current Flowing in the Electrodes'

GROUP C

The Blumlein–Browne–Willans Premium (value £20)
G. G. Gouriet — 'Bandwidth Compression of a Television Signal'

The Fahie Premium (value £15)
R. G. Medhurst, B.SC. — 'Harmonic Distortion of Frequency-Modulated Waves by Linear Networks'
R. G. Medhurst, B.SC., and G. F. Small, B.SC.(ENG.) — 'An Extended Analysis of Echo Distortion in the F.M. Transmission of Frequency-Division Multiplex'
R. G. Medhurst, B.SC., and H. D. Hyamson, B.E.E. — 'Discrimination Distortion in Frequency-Modulation Systems'
R. G. Medhurst, B.SC., and Muriel Hodgkinson, B.SC. — 'Intermodulation Distortion due to Fading in Frequency-Modulation Frequency-Division Multiplex Trunk Radio Systems'

The Frank Gill Premium (value £15). No award

The Heaviside Premium (value £15)
A. J. O. Cruickshank, B.SC., PH.D. — 'Generalized Operators for the Approximate Steady-State Analysis of Linear and Non-Linear Circuits'
A. J. O. Cruickshank, B.SC., PH.D. — 'A Note on Time Series and the Use of Jump Functions in Approximate Analysis'

The Paris Exhibition (1881) Premium (value £15). No award

The Webber Premium (value £15). No award

Oversea Premiums

For Senior Members (value £15). No award

For Students and Graduates under 28 years of age (value £10). No award

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The Willans Premium (value approximately £14) (Awarded triennially by The Institution of Mechanical Engineers and The Institution of Electrical Engineers in turn for the best paper since the last award by the Institution concerned, dealing with the utilization or transformation of energy treated especially from the view of efficiency or economy)

D. P. Sayers, B.SC., J. S. Forrest, M.A., D.SC., and F. J. Lane, O.B.E., M.SC. — '275 kV Developments on the British Grid System'

The Coopers Hill War Memorial Prize and Medal (value approximately £20) (Founded by the members of the Royal Indian Engineering College, Coopers Hill, in commemoration of members of the college who fell during the 1914–18 War, and awarded annually by The Institution of Civil Engineers, and triennially in turn by The Institution of Electrical Engineers, the School of Military Engineering, Chatham, and the School of Forestry, Oxford. The Prize is for the best paper on a professional subject published by The Institution during each three-year period; only Corporate Members under 35 are eligible)

L. R. F. Harris, M.A. — 'Time Sharing as a Basis for Electronic Telephone Switching: A Switched-Highways System'

Graduate and Student Premiums

		Section
A Premium (value £10)		
M. J. L. Willison	'Standardization and Simplification of Switchgear'	South Midland
Premiums (value £5 each)		
D. Chandra, B.SC.	'The Electrolytic Tank and the Use of a Self-Balancing Bridge'	South-East Scotland
A. R. Daniels, B.SC.	'The Cross-Field Generator and its Application to Closed-Loop Control Systems'	Bristol
A. J. S. Davidson, B.SC.	'An Electronic Servo Simulator'	North Scotland
J. Houldsworth	'Some Aspects of Logical Design in Electronic Circuits'	East Midland
P. D. House, B.SC.(ENG.)	'Electric Drives in the Paper Industry'	Rugby
G. E. Moreton, B.SC.(ENG.)	'Short-Circuit Testing of Electrical Equipment'	North Staffordshire
H. Myers, B.ENG.	'Aspects of Induction-Motor Development'	North Midland
Letters of Commendation		
J. Hawkins, B.SC.	'An Introduction to Flux-Reset High-Speed Magnetic Amplifiers'	East Midland
R. Hawley	'Electric Cable-Making Materials — Testing and Application'	North-Eastern
J. D. Smith, B.SC.	'Some Aspects of Distribution Planning'	North-Eastern
A. S. Watson, B.SC.(ENG.)	'Magnetic-Amplifier and Associated Circuitry'	South-West Scotland

WIRELESS TELEGRAPHY ACT, 1949

THE Postmaster-General made, on the 13th June 1958, an announcement in these terms:

'I hereby appoint, in accordance with section 9, sub-section (2), of the Wireless Telegraphy Act, 1949, Mr. O. W. Humphreys, C.B.E., B.SC., M.I.E.E., to be Chairman, and Mr. W. Nethercot, M.A., B.SC., F.INST.P., to be a member of the Advisory Committee on Interference from Ignition Systems.'

DIGITAL-COMPUTER TECHNIQUES

THE Committee of the Measurement and Control Section, with the approval of the Council, are arranging for Specialist Discussion Meetings on new digital-computer techniques to be held in the Institution building on the 16th and 17th February 1959.

The meetings, which are intended for specialist rather than for popular discussion, will cover the electrical-engineering aspects of digital computers. The uses of computers will not be considered, except where a particular use has given rise to new design problems. There will be a minimum of four sessions, each of which will consist of an opening lecture by an authority on the aspect concerned, a series of selected contributions, and a general discussion on the subject-matter of the particular session.

Provisionally, the sessions will deal with these subjects:

1. Character recognition

2. Peripheral equipment (magnetic tape, paper tape, fast printers, and other forms of input and output devices; and problems arising in their attachment to digital computers)

3. Low-temperature storage and switching devices

4. Special aspects of logical design, for example logical circuit techniques, fast-carry logic for adders, interrupt facilities, and the relation of logical design to reliability.

A more detailed programme of the sessions will be published later when exact information is available.

The Committee will be pleased to consider offers of contributions which, if selected, will be included in the programme. Anyone wishing to submit a contribution for consideration should send a synopsis of the proposed subject-matter to the Secretary of The Institution as soon as possible. Summaries of accepted contributions will be printed for circulation in advance of the meetings, with the names of selected contributors to the various discussions.

The meetings will be open to members and non-members of The Institution, and particulars of the registration and other fees will be announced in due course.

CONVENTION ON LONG-DISTANCE TRANSMISSION BY WAVEGUIDE

THE Committee of the Radio and Telecommunication Section, with the approval of the Council, have arranged a Convention on Long-Distance Transmission by Waveguide to be held in the Institution building on the 29th and 30th January 1959. Provisionally, the subject-matter will include theory and performance, measurement techniques and special microwave equipment. Further details may be obtained from the Secretary.

INTERNATIONAL CONVENTION ON TRANSISTORS AND ASSOCIATED SEMI-CONDUCTOR DEVICES

THE Committee of the Radio and Telecommunication Section, with the approval of the Council, have arranged an International Convention on Transistors and Associated Semi-Conductor Devices to be held in London from the 25th to 29th May 1959. The probable range of subjects will include materials, basic theory, measurement of characteristics, design and manufacture, and applications of transistors. Further details may be obtained from the Secretary.

HUNGARIAN ELECTRICAL ENGINEERING STUDENTS

THE Scholarship Fund for Hungarian electrical engineering students was set up as the result of the President's appeal in January 1957 for subscriptions to assist Hungarian refugee students who wished to complete their education in electrical engineering in this country. The Council have now agreed that the Fund should be wound up by the provision of five equal maintenance grants to students studying electrical engineering at technical colleges, an equal sum being retained for distribution to the next five Hungarian students who embark on similar courses.

EDUCATIONAL PUBLICATIONS

A NEW edition has just been published of *National Certificates in Electrical Engineering—Lists of Laboratory Experiments*. This publication replaces the *Lists of Laboratory Experiments* issued in February 1951, for the guidance of teachers. The introduction suggests that lecturers should continue to examine their laboratory schemes critically so that a continuous element of originality is introduced, as work in the laboratory is a vital feature of any National Certificate course. The new lists were prepared by a committee of teachers appointed by the Joint Committee for National Certificates (England and Wales) to stimulate these investigations and provide a focus for discussion between teachers. Electrical experiments only are included. Those for the S.1 and S.2 years of the Ordinary National Certificate course are listed under electrical engineering science and for the S.3 year under alternating current and direct current. The list for the Higher National Certificate course is arranged under a number of convenient topic headings.

In addition, the Part III Institution Examination papers of April 1956, October 1956, April 1957, and October 1957 have been reprinted. Each date covers a set of papers, and each set is obtainable from the Secretary for 1s. 6d. post free.

BENEVOLENT FUND

THE Court of Governors are pleased to acknowledge a further contribution of £1 to the Benevolent Fund, sent by an anonymous donor.

ELECTRONICS RELIABILITY

THE 5th National Symposium on Reliability and Quality Control in Electronics will be held on the 12th–14th January 1959 at the Bellevue-Stratford Hotel, Philadelphia, Pa., U.S.A. The symposium is sponsored jointly by the Institute of Radio Engineers, the American Society for Quality Control, the American Institute of Electrical Engineers, and the Electronic Industries Association.

Authors from outside the United States have specially been invited to present papers for reading at the Symposium or for inclusion in the proceedings.

CIVIL ENGINEERING IN SOUTH AFRICA

A CONVENTION is being planned to celebrate the 55th anniversary of the South African Institution of Civil Engineers. The convention is to be held at the University of the Witwatersrand, Milner Park, Johannesburg, from the 29th October to 1st November 1958, on the theme 'Civil Engineering in the Future of South Africa'.

Members interested in attending the celebrations should apply to the South African Institution of Civil Engineers, Kelvin House, 75 Marshall Street, Johannesburg.

COMMERCIAL AND INDUSTRIAL EDUCATION

THE 1958 annual residential conference of the British Association for Commercial and Industrial Education (BACIE) will take place at the College of Aeronautics, Cranfield, from the 25th to 27th September. Its theme will be the educational challenge of the second industrial revolution.

The conference chairman is Sir Godfrey Ince, G.C.B., K.B.E., the President of BACIE. Addresses will be given on these subjects: the industrial society of the future; the task of the schools and technical colleges; the responsibility of industry; the task of the universities and colleges of advanced technology; and the individual in the society of the future.

Members interested should get in touch with the Conference Secretary, BACIE, 26a Buckingham Palace Road, London S.W.1.

LONDON REPORT

MEASUREMENT AND CONTROL SECTION

Business Computers

THE Annual Lecture of the Measurement and Control Section was delivered by Dr. A. T. Starr on the 6th May, the title being *Some Case Histories of Business Computers in the U.S.A.* In his introduction Dr. Starr said that he would have little quantitative information to give on the economics of business machines, because it was almost impossible to prise such information out of the users, and he suggested some reasons why they might be unwilling to impart it, even if it were known. It was relevant that he did not know of any detailed account of the savings made by installing cash-register machines, or even typewriters.

Dr. Starr then described six major installations in the United States. The first of these was the American Airlines Reservisor system, an example of specially designed equipment rather than use of a standard computer. A magnetic drum is used to store aircraft reservations made by 120 agencies, and the company states that the expansion of its business could not have continued without it. A most interesting feature was the reliability: over seven years' operation the single equipment had achieved an availability figure of 99·8%. Recently it has been duplicated, so that if a circuit develops a fault the duplicate unit takes over and the fault is indicated. By this method it is hoped to obtain nearly 100% reliability.

Dr. Starr's further examples each had a most interesting emphasis on a different aspect of the subject. In the case of the installation of a digital computer by the Bank of America, initially for loan-accounting purposes, this emphasis was on a detailed history of the initial study, the ordering of the machine, the time-table of systems study and programming, and the delivery of the machine and its initial and final loading. Impressive figures were given for the time saved by the use of a computer by Pan American World Airways, mainly for ticket processing and accounting. One company could not use computers at all until random-access stores had been developed. Finally Dr. Starr mentioned a company which has no computer, but which has a data-processing centre serving 89 stations all over the country by teleprinter network; this experiment has been watched with great interest from this country, but it has not yet reached the stage where Dr. Starr could report on its success or failure.

Assessing the over-all position, Dr. Starr thought that American management was more go-ahead over computer installation than management in this country. It certainly was not the case that the attitude of the workers was any more restrictive here than in the United States. It had been said that the Americans had attacked office automation like a bull at a gate; he thought that in most cases the bull had got through the gate.

After the lecture, which was well attended by members and guests, there was a short discussion. R. H. T.

Summer Visit

Approximately 100 members and their ladies took part in the Measurement and Control Section's Summer Visit on the 7th June 1958. Led by Mr. H. S. Petch, Chairman of the Section, they assembled at 10 a.m. at the B.B.C. Television Centre, Wood Lane, where they were received by Mr. L. W. Turner and Mr. L. G. Dive of the Engineering Information Department. After being shown round the Centre, the party visited the television studios at Lime Grove and Riverside. Members were delighted at being able to see a rehearsal of a serial programme. The B.B.C. invited the party to lunch at the Television Centre, when Mr. R. T. B. Wynn, Chief Engineer, presided. Mr. H. J. L. Pulling, Controller of Television Service Engineering, and Mr. E. L. E. Pawley, Head of the Engineering Services Group, were also present. After a most enjoyable visit, the party left Wood Lane for Polesden Lacey at about 2.30 p.m.

The National Trust Regency villa was reached an hour later, and a guided tour was made of this charming house, which until 1942 was owned by the Hon. Mrs. Ronald Greville. The large selection of furnishings, paintings and objects aroused great interest and evoked many questions, particularly from the ladies. After taking tea at the adjacent tea rooms, the party left for the Electricity Council's Training Establishment at Horsley Towers.

On arrival there they were received by Mr. D. Williams, Resident Tutor, who outlined the work of the establishment. Examples of metering equipment, models and instruments used in technical training were on display. The party was entertained to dinner by the London Electricity Board, whose Chief Engineer, Mr. L. H. Welch, presided. Mr. R. G. Bellamy, Education and Training Officer, was also present.

After words of thanks from Mr. Petch and Mr. J. K. Webb, Chairman-Elect, the return journey began at about 8.15 p.m., and the Institution building was reached at 9.30 p.m., at the close of a most successful day.

ORDINARY MEETING

Artificial Satellites

AT the Ordinary Meeting on the 10th April 1958 the chair was taken by Sir Harold Bishop, C.B.E., Past-President. After the customary ceremony of welcoming new members, the Page Prize for the current session was presented to Mr. F. W. Stainer, and Institution Prizes were presented to candidates reaching the requisite standard in the examination for the Higher National Certificate in Electrical Engineering.

Mr. J. A. Ratcliffe introduced his lecture on *Radio Observations on Artificial Satellites* by likening the earth's atmosphere to a swimming pool 30ft deep, and asked his audience to contemplate the questions which would be asked by someone living at the bottom of so much water without any chance of ever seeing the top. Problems of a similar nature arise with the atmosphere. What kind of radiation is coming in on the outside of this ocean of air? What is the constitution of sunlight before it has gone through the equivalent of 30ft of water? What are cosmic rays like before entering the atmosphere? How do the various properties of the air vary with height? What produces the changes in the ionosphere which have such a profound influence on radio transmission? These

are the problems which ionospheric and atmospheric physicists have long been trying to solve.

Mr. Ratcliffe considered mainly the results obtained from observation on the first two Russian satellites, since the frequencies of their radio emissions (20 and 40 Mc/s) were more suitable for ionospheric investigations than the 108 Mc/s used with the American satellites; and also because the Russian satellites were more readily observable in the United Kingdom. Observations of the radio transmissions can be used (i) to help determine the satellite's orbit; (ii) to find out about the ionosphere; and (iii) to telemeter back to the earth information about various characteristics of the atmosphere measured by instruments in the satellite.

The orbit may be determined by observing the direction of arrival of the received signal, using suitably designed aerial systems, and by observations of the Doppler effect, as a result of which the frequency of the signal varies according to whether the transmitter is approaching or receding from the observer.

Having shown how the orbit may be determined, Mr. Ratcliffe went on to describe how observations of changes in the orbit lead to information about the density of the atmosphere, the shape of the earth and its gravitational effects. There have been two conflicting theories about the density of the upper atmosphere, and the knowledge gained from the satellite experiments shows clearly that the theory indicating the lower density is the correct one.

Mr. Ratcliffe discussed finally the information which can be obtained from observing the fading of the received signal. This fading may occur for several reasons. First, the satellite itself is rotating, and so, therefore, are its associated transmitting aerials, thus causing the signal strength to vary with the rotation; secondly, the satellite goes through major irregularities of electron density in the ionosphere; and, thirdly, the Faraday effect produces a rotation of the plane of polarization of waves passing through the ionosphere. It is possible to separate out these three types of fading and to determine various characteristics of the ionosphere. For example, observations of the Faraday effect enable information to be derived about the total electron content of the ionosphere.

In conclusion Mr. Ratcliffe said that as a result of the experience now gained it is certain that more detailed and accurate measurements will be made on future satellites, thus leading to the acquisition of much valuable knowledge about the earth and its atmosphere.

Although it is not usual to have a discussion after such a lecture at an Ordinary Meeting, the Chairman felt that on this occasion the subject was so fascinating that a break with tradition might be made; and there ensued a lively series of contributions from many speakers. Those taking part in the discussion included Mr. C. E. Strong, Dr. E. V. D. Glazier, Mr. J. D. Middleton, Mr. E. H. Cooke-Yarborough, Dr. J. H. Blythe and Dr. J. A. Saxton. The lecturer's versatility was not defeated by a wide range of questions covering such topics as the accuracy of launching speed required for satellites, the choice of plane for the orbit, the burning-up of satellites on re-entering the earth's atmosphere, and the possible use of reflections from satellites of the radiation from high-powered transmitters on the ground.

The meeting finally ended when the Chairman moved a warm vote of thanks to Mr. Ratcliffe, which was carried with acclamation by an appreciative audience. J. A. S.

(A special article based on this lecture will appear in a future issue of the *Journal*.)

RADIO AND TELECOMMUNICATION SECTION

High-Quality Loudspeakers

As the author suggested, the weather may have had something to do with it. The Chairman was surprised and so was much of the audience, for a paper on loudspeakers, it had been widely felt, was just the thing to provoke some violent clashes of opinion. Consequently, on the 23rd April, when Mr. D. E. L. Shorter had introduced his paper *A Survey of Performance Criteria and Design Considerations for High-Quality Monitoring Loudspeakers*, the audience settled down to await the discussion with much of the pleasurable anticipation of impending bloodshed that animates the crowd at a bullfight. In this respect, though in this respect alone, the meeting may have been a disappointment to some of the audience, for in the event the discussion turned out to be a notable exercise in general agreement. All was, in fact, peace if not quite so markedly light. The air of general amity was underlined at an early stage by Mr. G. A. Briggs's offer to supply his competitors with information that they were rather unlikely to require.

Almost the only hint of a dissident note in the discussion was Mr. P. P. Eckersley's suggestion that the subjective assessment of loudspeaker performance might be vitiated by the faults of the microphone used and that even objective measurement might be suspect because of acoustic interaction between the loudspeaker and the measuring microphone. The author gave reasons why Mr. Eckersley might feel reassured on both these points but noted that nevertheless it was easy for an experimenter to mislead himself and others by applying conditions particularly favourable to one loudspeaker in comparative tests with another. This cautious approach to the difficulties of objective and subjective appraisal of loudspeakers was a feature both of the paper itself and of the discussion. It was well summarized by the author's characteristic remark that it only goes to show how careful you have to be in these matters.

Both in the paper and in the discussion it was brought out that the high-quality monitoring loudspeakers used by broadcasting and recording organizations had an importance out of proportion to their numbers or cost because they inevitably conditioned the technical quality of the programme material available on record or by radio for which other loudspeakers were developed and used.

It was agreed that, although a great deal was known about the objective performance of loudspeakers, there was at the present time no complete set of objective criteria by which the relative merits of different designs might safely be compared. Indeed, it appeared that those most experienced and familiar with the art would undertake the appraisal of a loudspeaker on the basis of its measured performance with about the same degree of confidence with which they would approach the capture of an angry scorpion. In both cases the task seems possible but fraught with danger and of uncertain outcome.

To convey some idea of what is involved, a demonstration was given in an adjoining room in which samples of different kinds of programme material were reproduced alternately on two high-quality loudspeakers, performance data for which were displayed. No attempt was made to 'sell' either loudspeaker, but listeners were given the opportunity of attempting to correlate subjective judgment with the objective data.

While it is characteristic of the professional approach to all loudspeaker assessments, caution appeared to be particularly

necessary when comparing the moving-coil speaker with the new types of wide-range electrostatic speaker. Whereas the former is essentially a device of high acoustic impedance, the latter has a low impedance, and its performance is therefore more susceptible to influence by the acoustic conditions in which it is used. Indeed, Mr. P. J. Walker made the important point that when the conditions in which a moving-coil and an electrostatic loudspeaker are being compared favour the former, it does not at all follow that interchanging the two units would be advantageous to the latter. Mr. Shorter agreed with Mr. Walker that, while experience with moving-coil loudspeakers over many years had taught us much about the interpretation of objective measurements, a good deal more experience with electrostatic loudspeakers would be necessary before measurements on them could be interpreted even with the same rather modest confidence.

The title of this paper had made it clear that it dealt with a particular, rather specialized aspect of loudspeaker technique, and it was perhaps because of this that the audience was somewhat smaller than might have been expected for a paper and discussion on loudspeakers. The discussion was for the most part confined to members highly experienced and expert in this field, and it was at a high level of competence and responsibility. The absence of violent controversy did not entail any lack of interest or of wit. The discussion was, in fact, worthy of the paper itself, which is a valuable and highly professional contribution to a subject that it is difficult to make at once interesting to those skilled in the art and accessible to those who are not. H. D.

NEWS *from the Centres*

NORTH MIDLAND CENTRE

Problems and Answers

THE seventh Ordinary Meeting, on the 18th March, was held at the Bradford College of Technology, when the Chairman, Mr. A. J. Coveney, presided over an attendance of some 270 members and friends. The speakers, Mr. A. T. Crawford and Mr. C. H. Lackey, were introduced by the Chairman, who said how much we were all looking forward to their paper on *Circuit-Breaking and Power-System Problems*. The lecture was accompanied by many interesting experiments and exhibits dealing with specific problems in the field of circuit-breaking and power systems and made clear points which many members had hitherto considered rather obscure. A vote of thanks was proposed by the Vice-Chairman, Mr. J. D. Nicholson, who commented on the able way in which the paper was presented and the very interesting demonstrations, which showed many of the problems faced by present-day switchgear designers and how these problems are affected by and associated with power-system design. In many ways the lecture was a small Faraday Lecture, and Mr. Nicholson emphasized the great amount of work which had gone towards its preparation. The authors replied by saying how much they had enjoyed their visit to Bradford.

Rowntree's and York

The York Meeting was held on the 1st April, and following the usual custom a works visit was arranged during the afternoon—this year to Rowntree's factory. This proved interesting and instructive, and members were particularly struck by the orderly and tidy layout of the factory and the general air of efficiency. At the end of the visit, the Chairman proposed a vote of thanks to Rowntree's and in particular to Mr. A. King, the Electrical Engineer. Thanks were also offered to Mr. T. Duerden for the efficient arrangements he had made.

The eighth Ordinary Meeting, at the Royal Station Hotel, York, was attended by 95 members and visitors. Mr. A. B. Gillespie presented his paper on *The Control and Instrumentation of Nuclear Reactors*, which described many problems of both conventional and specialized equipment used with reactors and covered the subject under three general headings of measurement, control and safety. After a stimulating and interesting discussion, a vote of thanks was ably proposed by the Vice-Chairman, Mr. F. W. Fletcher, who paid tribute to the manner in which the author had dealt with such an abstract and complex subject.

Annual General Meeting

The Annual General Meeting was held in Leeds on the 6th May; 87 members and guests being present. We were honoured by the presence of Mr. C. T. Melling, a Vice-President, who addressed the meeting. After the normal business of the evening the Chairman reviewed the activities of the 1957–58 Session—a most successful year. He then introduced Prof. Asa Briggs, Professor of Modern History in the University of Leeds, who gave a lecture entitled *A Visit to India*. This proved a most interesting discourse from a traveller who obviously had a lively curiosity, combined with a vivid sense of history and the ability to convey it in such an interesting manner with fascinating coloured slides.

During the evening Dr. E. C. Walton made an appeal on behalf of the Benevolent Fund and followed this up by a collection which resulted in an amount of £15 3s. 6d.

The Chairman said what a privilege and pleasure it was to introduce a Vice-President; it was an honour to have him with us, and the Chairman extended a cordial welcome from the North Midland Centre. Mr. Melling has given years of valuable service to The Institution, being a Member of Council, a Member of the Education and Training and Membership Committees and a Past-Chairman of the Utilization Section. We were grateful that he had found time to come from London and be with us.

In his reply, the Vice-President thanked the Chairman cordially for his remarks and welcome, pointing out that Leeds was not an entirely strange place, since he had on one occasion lived there while with the Yorkshire Electric Power Co. Mr. Melling said how pleased he was to hear of the activities of the Sheffield Sub-Centre and the various Districts, including the new District now starting at Grimsby. He was particularly interested in the support given to the Graduate and Student Section and stressed that educational work now being carried

out and improved on is essential for the preservation of ideals and standards of living. He brought with him the greetings of the President, who was in Australia, and wished success for the future of the Centre.

Hull District Meeting

The fifth District Meeting of the 1957–58 Session in the Kingston-upon-Hull area was held on the 27th February, when Mr. K. S. Brazier presented for discussion the paper entitled *British Columbia–Vancouver Island 138 kV Submarine Power Cable*, of which he was a co-author with Messrs. T. Ingledow, R. M. Fairfield, E. L. Davy and J. N. Gibson. The paper, which was illustrated by many excellent slides, dealt with the design, manufacture and installation of the two underwater-cable sections of the transmission line between the Arnott substation, on the mainland of British Columbia, and the Stratford switching station, on Vancouver Island. Five single-core gas-pressure cables are used for each of these, the crossing from the mainland to the nearest island being 14·7 miles and that across the Trincomali Channel being 2·9 miles. The cables were manufactured in continuous lengths and laid by H.M.C.S. *Ocean Layer*, and the ingenious and impressive method of laying was very fully described by a film presented at the close of the lecture. Mr. Brazier had intended to exhibit demonstration models showing the handling of the cable during laying, but owing to the severe wintry weather conditions prevailing at the time of the meeting, these appeared to have been lost in a snowdrift *en route* to Hull. After the reading of the paper and the viewing of the film, a discussion was opened by Mr. H. Hilton. Nine other local members took part in this, and of the many questions put to Mr. Brazier was one which introduced the relative merits of direct and alternating currents for submarine-cable transmission circuits. A vote of thanks to Mr. Brazier was then put from the Chair by Mr. W. S. Milner, Convener of the Hull Meetings, and this was carried in the usual hearty manner.

W. J. W.

Catterick District Meeting

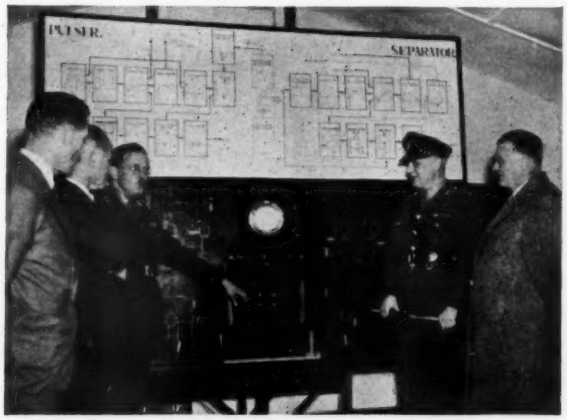
On the 13th May about 100 members and visitors gathered at Catterick, where they were shown methods of training and new equipment used at the School of Signals. The meeting was opened by Lt.-Col. R. G. Miller, who welcomed the Chairman, Mr. A. J. Coveney, and the other visitors and said that, although there were to be changes at the School of Signals, he was sure that these District Meetings would continue.

The lecturer, Mr. J. N. Cruickshank of the Radar Research Establishment, was then introduced. His subject was *Recent Developments in Microwave Engineering*.

He began by explaining the need for using microwaves and their advantages over radiations at longer wavelengths. Different techniques were needed for conveying power at these frequencies, and Mr. Cruickshank outlined the desirable characteristics of transmission lines and waveguides. He also explained the functions of microwave circuit components, such as phase shifters, cavity resonators, directional couplers and ferrite gyrators, and contrasted these circuit-elements with those used at lower frequencies. Generators, oscillators and amplifiers used at microwave frequencies differ greatly in every way from those for lower frequencies, and Mr. Cruickshank stressed the great strides recently made in klystron and travelling-wave-tube development.

At this stage there was a short break for questions and a chance to examine the pieces of microwave equipment that Mr. Cruickshank had brought with him.

The lecturer went on to explain the 'maser' class of amplifiers and oscillators. These have the advantage of extremely low noise factor in the case of amplifiers and stability of the highest order in the case of oscillators. Such low-noise amplifiers were required in radio-astronomy, where signal strengths were very weak.



Lt.-Col. R. G. Miller shows Mr. A. J. Coveney one of the exhibits at the School of Signals, Catterick

Mr. W. S. Milner, who opened the discussion, commented on the focusing of the beam in the ammonia maser. Other questioners were quick to follow on, and each was readily and clearly answered by Mr. Cruickshank. Brig. R. G. Yolland thanked the lecturer for his most interesting paper.

Before the close of the meeting the Chairman announced that Lt.-Col. Miller was leaving the School of Signals. Mr. Coveney went on to say how much he appreciated Lt.-Col. Miller's efforts as Founder-Convener of the Catterick District Meetings and wished him well in his future appointment.

C. S. R.

Annual Golf Match

The annual golf match was held on the 3rd June at Sandmoor Golf Course, when 54 people played. Although the weather was bad for the early starters, it gave way to perfect conditions for the rest of the day, so that everybody thoroughly enjoyed themselves. A hundred people attended the Dinner in the evening, and the Chairman thanked the two guests of honour, Mr. W. J. Richards, the Captain, and Mr. Bates, the Secretary of the Sandmoor Club. The Chairman said how pleased we always were to visit Sandmoor and also thanked Mr. Barnes, the Club professional. Mr. Richards made a suitable reply. The Chairman sincerely thanked Mr. F. W. Fletcher, who stepped into the breach at short notice owing to the unavoidable absence of Mr. J. N. Nicholson, the Golf Committee Secretary. The Chairman also referred to the able help given by Miss F. J. Evers. Mr. Fletcher then announced that the Woodham Challenge Cup was won by Mr. R. D. Graham (now in his 75th year) after being runner-up for the last two years. Mr. A. J. Evans qualified for the second prize. Mr. H. S. Moody thanked the firms and individuals who had donated gifts for the auction, and Mr. W. Plumb who had made the journey from Southport

in order to run the auction in his usual inimitable style. It was hoped the results of this auction would be at least equal to last year's effort for the benefit of the Benevolent Fund.

Annual Dinner-Dance

The Annual Dinner-Dance, held at the Cairn Hydro Hotel on the 28th March, was presided over by the Chairman; 327 visitors, friends and their ladies attended. After a brief

Mr. A. J. Coveney, Chairman of the North Midland Centre, and his wife at the Annual Dinner-Dance on the 28th March

word of welcome, Dr. E. C. Walton made an appeal on behalf of the Benevolent Fund which met with a very generous response. Dancing concluded a very successful function.

Careers Convention at Keighley

The Centre represented The Institution at the Keighley Careers Convention from the 13th to 17th May. The Chairman and the following members of the Committee formed a rota of attendance to act as advisers: Prof. G. W. Carter, Dr. E. C. Walton, Dr. O. I. Butler, Mr. N. S. Goddard, Dr. G. N. Patchett and Mr. J. L. Browell. They were able to provide full information concerning the necessary training courses leading to corporate membership, together with details concerning many well known sandwich schemes, to students and their parents who attended this convention. While the majority of the younger people were concerned with craft apprenticeship, a few should benefit from the advice which our representatives were able to give to them. Our thanks are due to The Institution for the loan of the demonstration panels and charts, which were erected in the main exhibition hall and in the adviser's room, and to our members who voluntarily attended on behalf of The Institution.

W. J. W.

RUGBY SUB-CENTRE

Report of the 1957–58 Session

Another successful session of lectures and papers in the Rugby Sub-Centre was brought to a close by the District Meeting held at Banbury on the 23rd April, when a lecture entitled *Recent Developments in Mains-Frequency Induction Heating and Melting* was given by Mr. E. May. The meeting was held at Wincott's Café, and there was a total attendance of 52. The subject was of particular local interest, in view of the aluminium works and laboratories which are located at Banbury. The discussion, therefore, was extremely lively and interesting. The thanks of the Sub-Centre are due to the local member of the Committee, Mr. J. H. Fearon, who was responsible for making the detailed arrangements.

The lecture which created the greatest interest during the session was a talk by the Hon. Alexander L. Hood on *The Financial Structure of the Electrical Manufacturing Industry*. This was given on the occasion of the joint meeting of the Sub-Centre and the Graduate and Student Section. The lecture hall was filled to capacity, and some members may have gone away disappointed owing to their inability to obtain admission. While the subject was not technical, it nevertheless proved extremely interesting and was dealt with in a most able and instructive way by the speaker.

The first of what is hoped will be a series of Sub-Centre Dinners was held on the 21st November 1957, and a report concerning this appeared in the January *Journal*, p. 49.

The Engineers' Ball was organized this year by a committee on which were represented the Sub-Centre, the local Engineering Society, and the Rugby Branch of The Institution of Mechanical Engineers. It took place at the Leofric Hotel, Coventry, on the 9th May and was very well supported, the only complaint being that the dance floor tended to be overcrowded late in the evening.

The new Sub-Centre Committee has now been elected: Mr. E. M. Price is the new Chairman, and Messrs. J. H. Fearon and W. S. Melville have now retired. The thanks of the Sub-Centre are due to them for the excellent support they have given to the work of The Institution in Rugby. E. S. H.

OVERSEA ATTENDANCE REGISTER

During the period 17th June to 16th July 1958 the following members called at the Institution building and signed the Attendance Register of Oversea Members:

BARGE, R. M. (Sydney)
BOYCE, K. M. (Charleville, Australia)
BRIARS, E. (Nicosia, Cyprus)
CATOR, F. L. (Johannesburg)
DA COSTA, F. A. V. (Praia da Rocha, Portugal)
DAVIES, C. S. (Freetown, Sierra Leone)
DOUGLAS, T. K. A. (Salisbury, S. Rhodesia)
ELDER, J. A. (Kuala Lumpur, Malaya)
GRACE, J. N. G. (Singapore)
HODGETTS, E. (Teheran, Iran)
HUME, J. R. (Townsville, Australia)
JONES, E. (Adelaide)
KERRICH-WALKER, H. V. (Concession, S. Rhodesia)
LANGLEY, G. A. (Kuala Lumpur, Malaya)
LIANG, F. J. (Singapore)
MARKS, R. G. (Johannesburg)
PITHER, A. G. (Hawthorn, Australia)
PUGSLEY, E. R. J. (Baghdad, Iraq)
SINGH, H. (India)
STOCK, J. M. (Kampala, Uganda)
VAUGHAN, J. (Lagos)
WADE-COOPER, F. (Calcutta)